

PM009 – 13 December 2023

Update on PINNs

Application to Urban Wind Field Dispersion Studies

Script Version v4

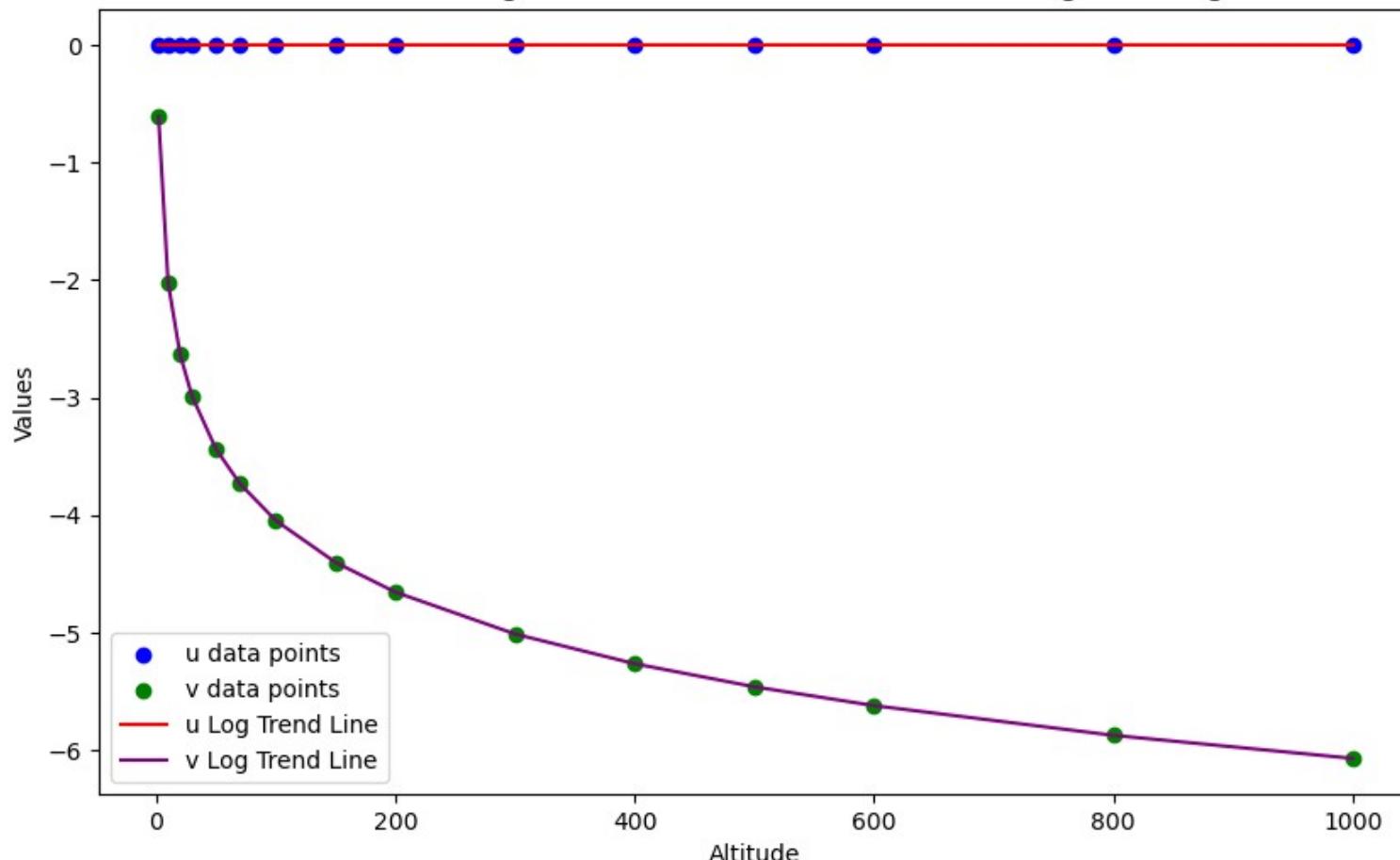
- 1) PINN is now completely customizable – customizable input and output parameters, batch normalization, dropout rate, neuron number, number of hidden layers – all options in the config file (PM007)
- 2) Saving of all the losses (not just the total loss) (PM007)
- 3) Plotting of loss vs epochs now automatic (PM007)
- 4) Boundary conditions – relaxed no slip condition included (PM007)
- 5) New angles included (PM007)
- 6) Smaller batch sizes (I disagree) – customizable from config file (PM007)
- 7) Testing and Predicting Loss during training phase (PM008)
- 8) Inlet Boundary Conditions added (PM008)
- 9) Inlet Boundary for the Z-direction made to follow a log equation (PM009)
- 10) Debugged for no slip loss BC (PM009)
- 11) Script is being modified for TPU use (PyTorch → Tensorflow) (PM009)

$$u = 0.00 * \log(\text{Altitude}) + 0.00$$

$$R^2 = 0.000$$

$$v = -0.88 * \log(\text{Altitude}) + 0.00$$

$R^2 = 1.000$ Scatter Plot with Logarithmic Trend Lines for u and v for Angle = 0 degrees

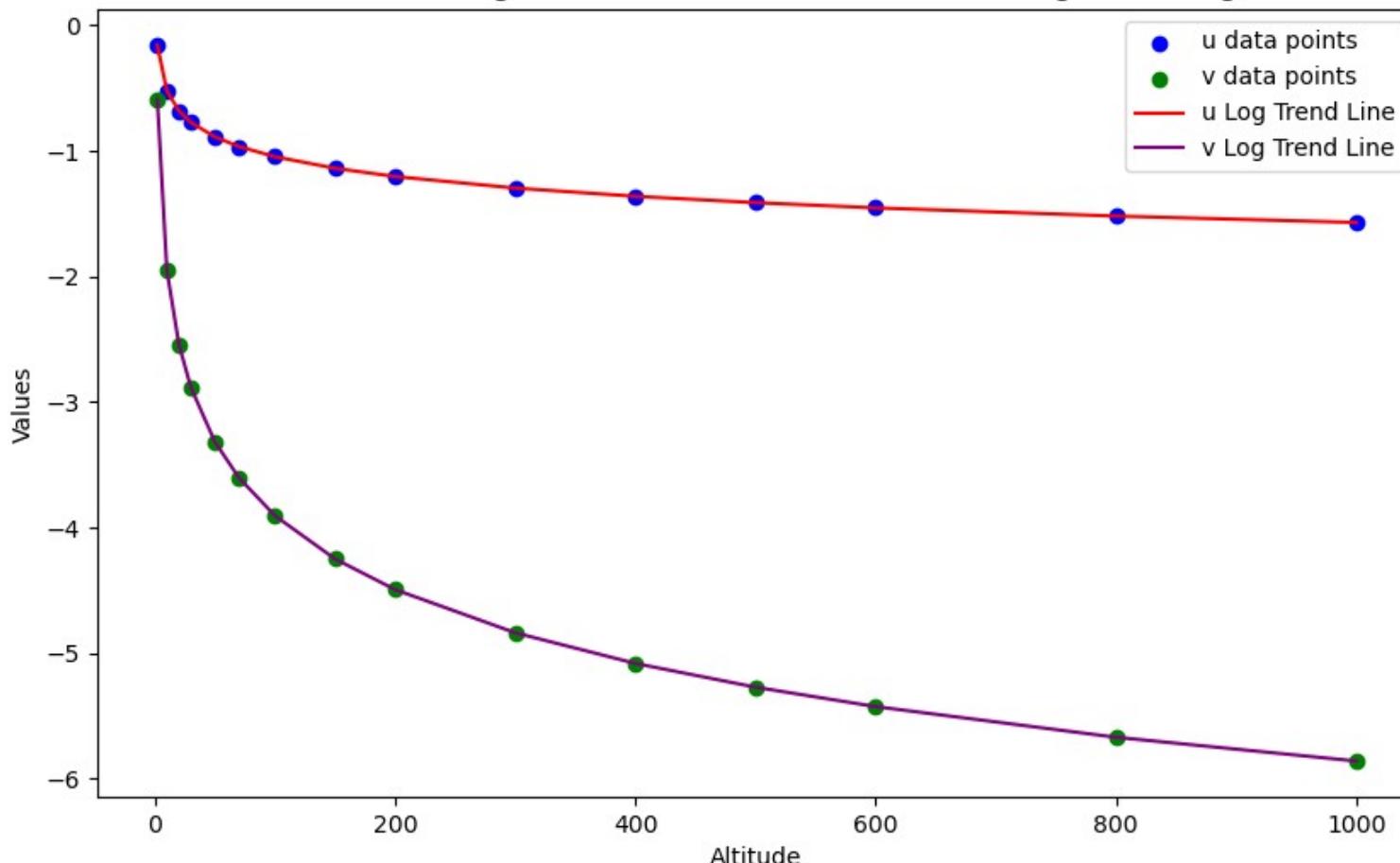


$$u = -0.23 * \log(\text{Altitude}) + 0.00$$

$$R^2 = 1.000$$

$$v = -0.85 * \log(\text{Altitude}) + -0.00$$

R² = 1.000 Scatter Plot with Logarithmic Trend Lines for u and v for Angle = 15 degrees

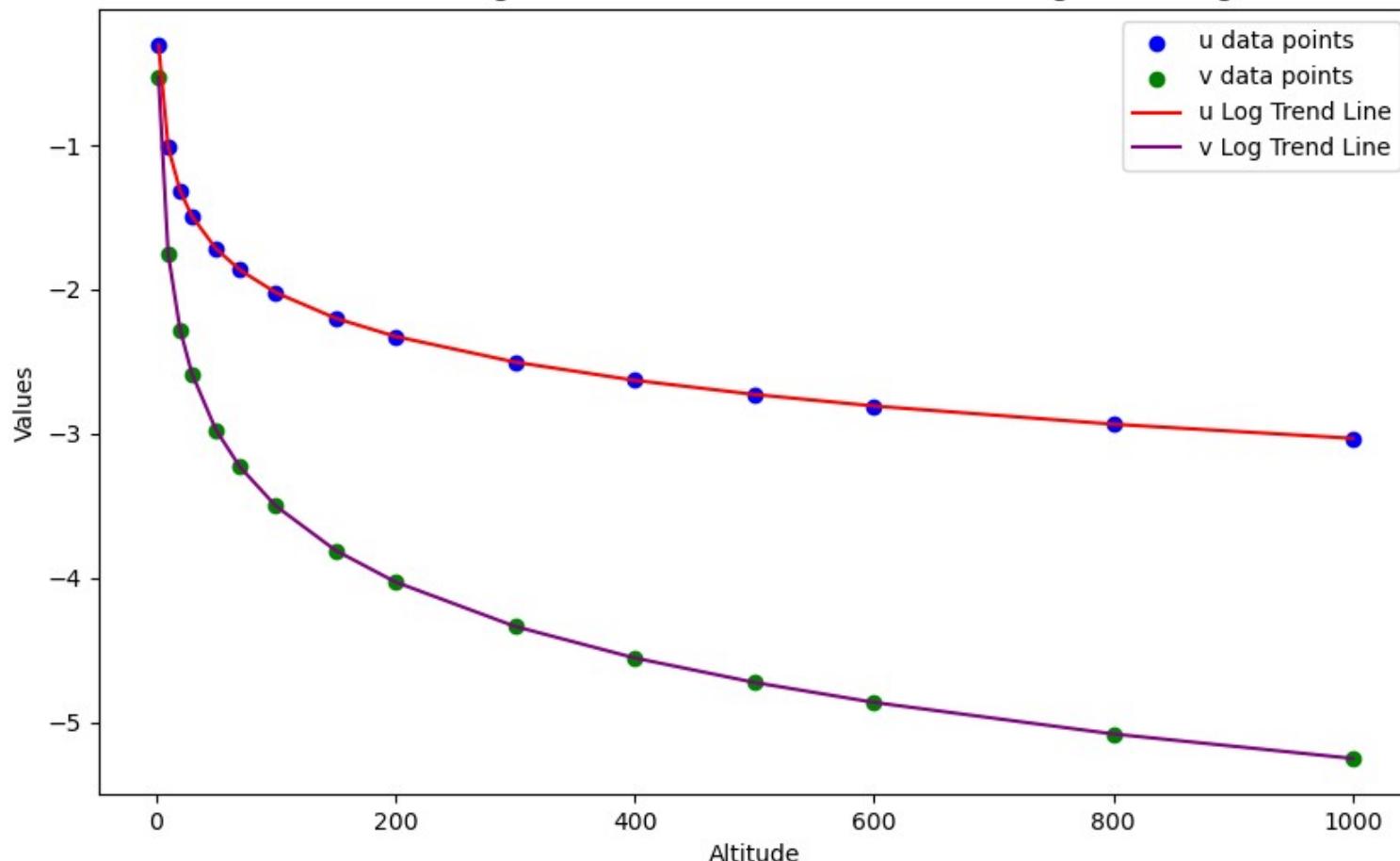


$$u = -0.44 * \log(\text{Altitude}) + -0.00$$

$$R^2 = 1.000$$

$$v = -0.76 * \log(\text{Altitude}) + 0.00$$

$R^2 = 1.000$ Scatter Plot with Logarithmic Trend Lines for u and v for Angle = 30 degrees

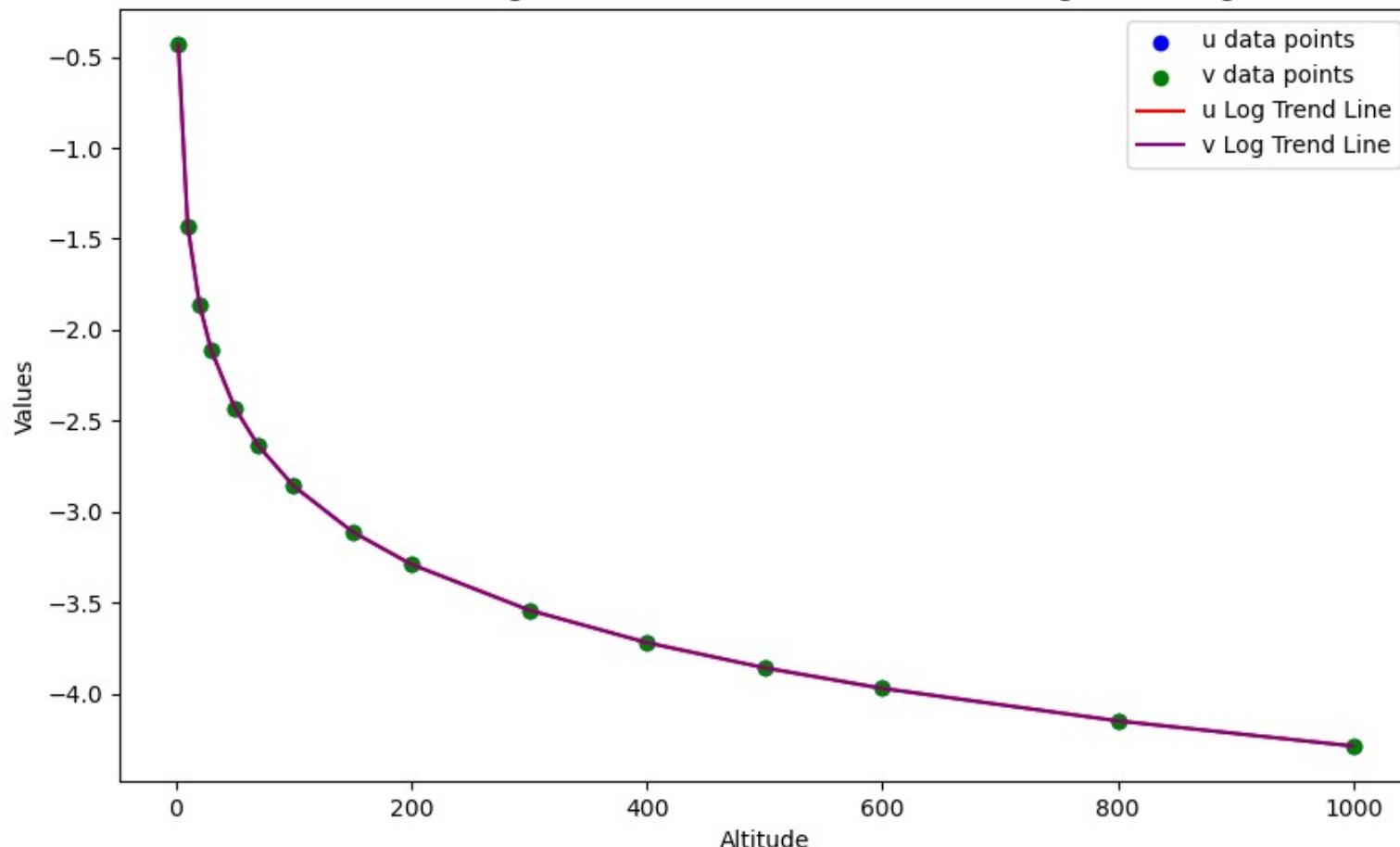


$$u = -0.62 * \log(\text{Altitude}) + -0.00$$

$$R^2 = 1.000$$

$$v = -0.62 * \log(\text{Altitude}) + -0.00$$

R² = 1.000 Scatter Plot with Logarithmic Trend Lines for u and v for Angle = 45 degrees

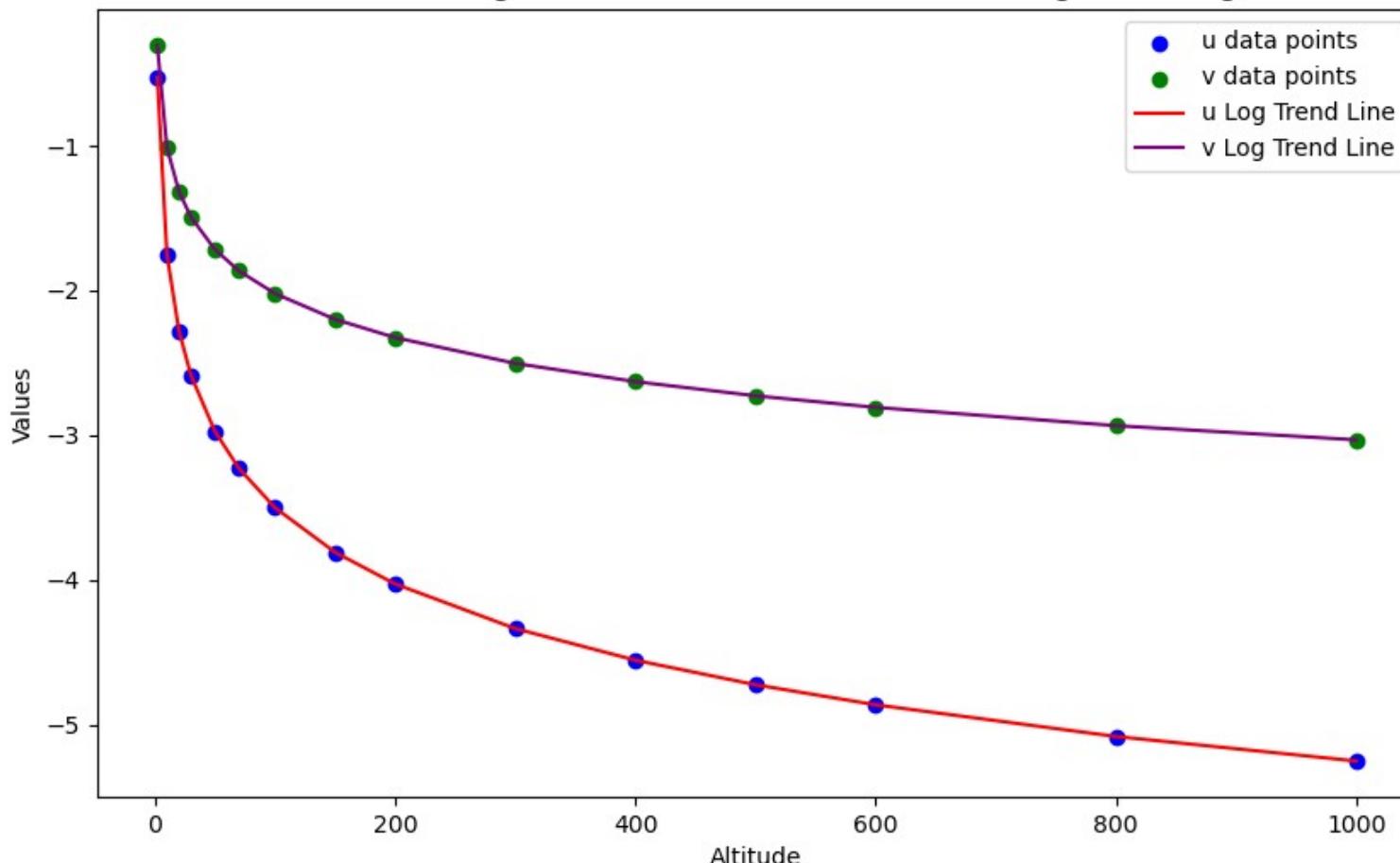


$$u = -0.76 * \log(\text{Altitude}) + 0.00$$

$$R^2 = 1.000$$

$$v = -0.44 * \log(\text{Altitude}) + -0.00$$

$R^2 = 1.000$ Scatter Plot with Logarithmic Trend Lines for u and v for Angle = 60 degrees

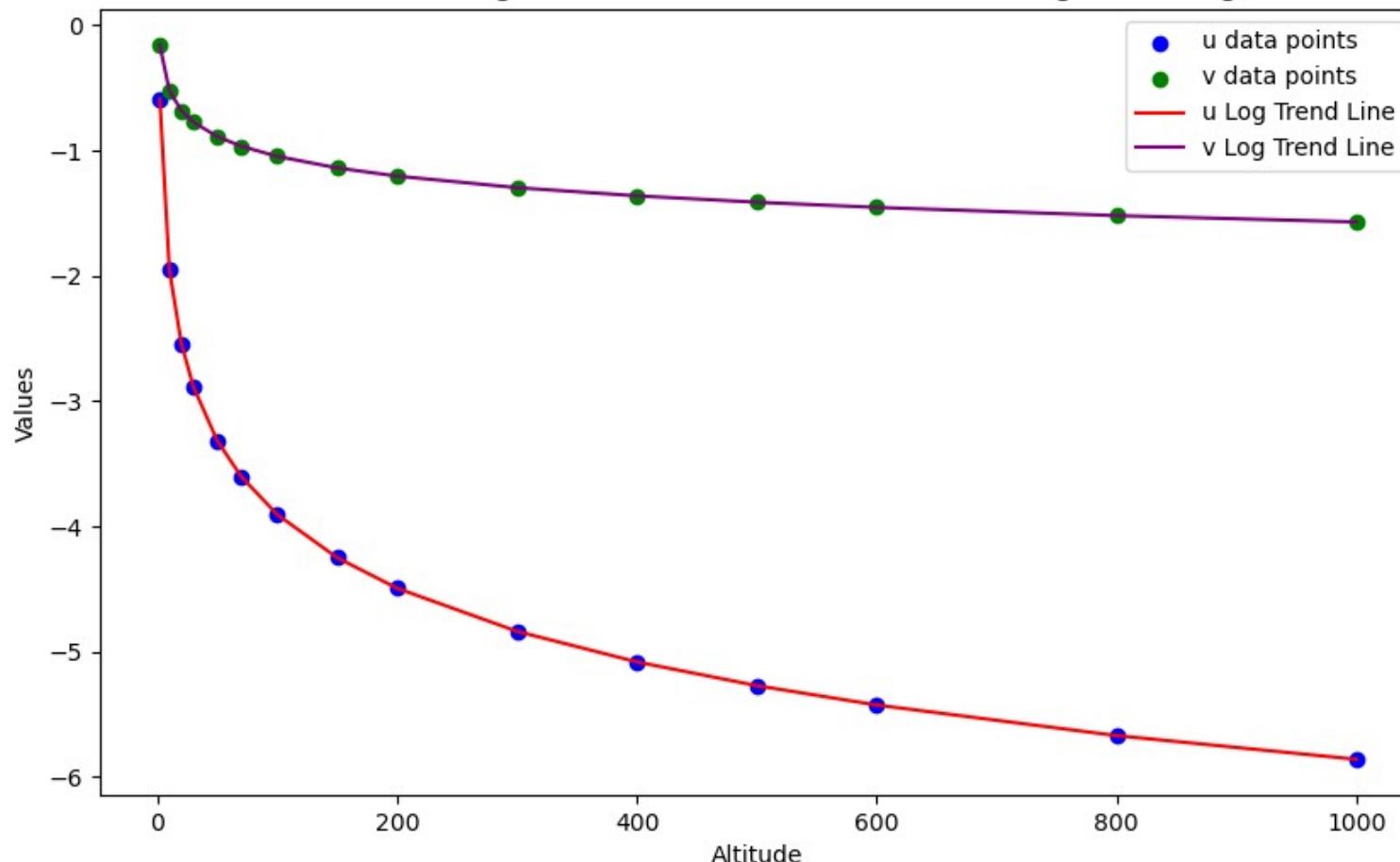


$$u = -0.85 * \log(\text{Altitude}) + -0.00$$

$$R^2 = 1.000$$

$$v = -0.23 * \log(\text{Altitude}) + 0.00$$

R² = 1.000 Scatter Plot with Logarithmic Trend Lines for u and v for Angle = 75 degrees

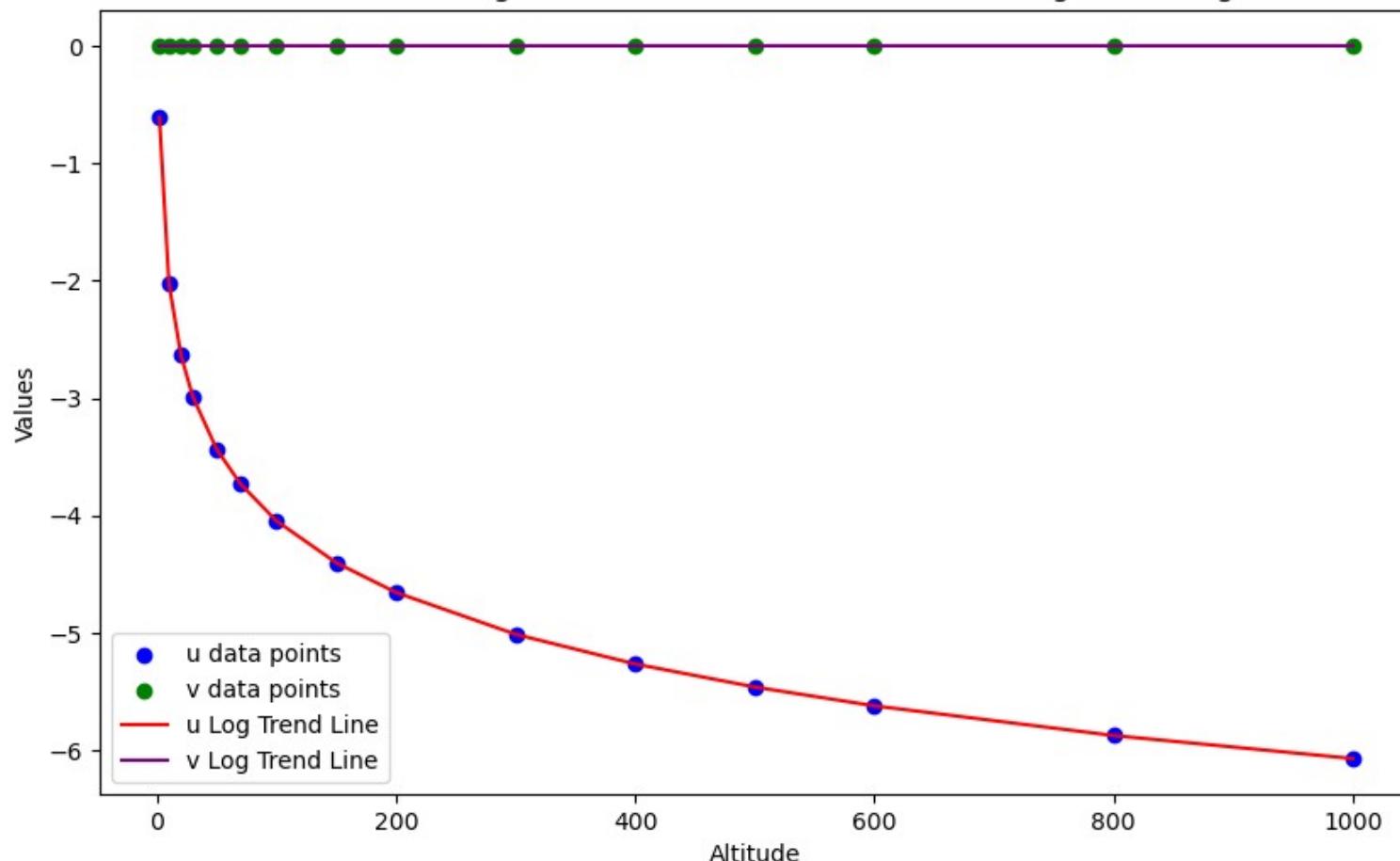


$$u = -0.88 * \log(\text{Altitude}) + 0.00$$

$$R^2 = 1.000$$

$$v = 0.00 * \log(\text{Altitude}) + 0.00$$

R² = 0.000 Scatter Plot with Logarithmic Trend Lines for u and v for Angle = 90 degrees

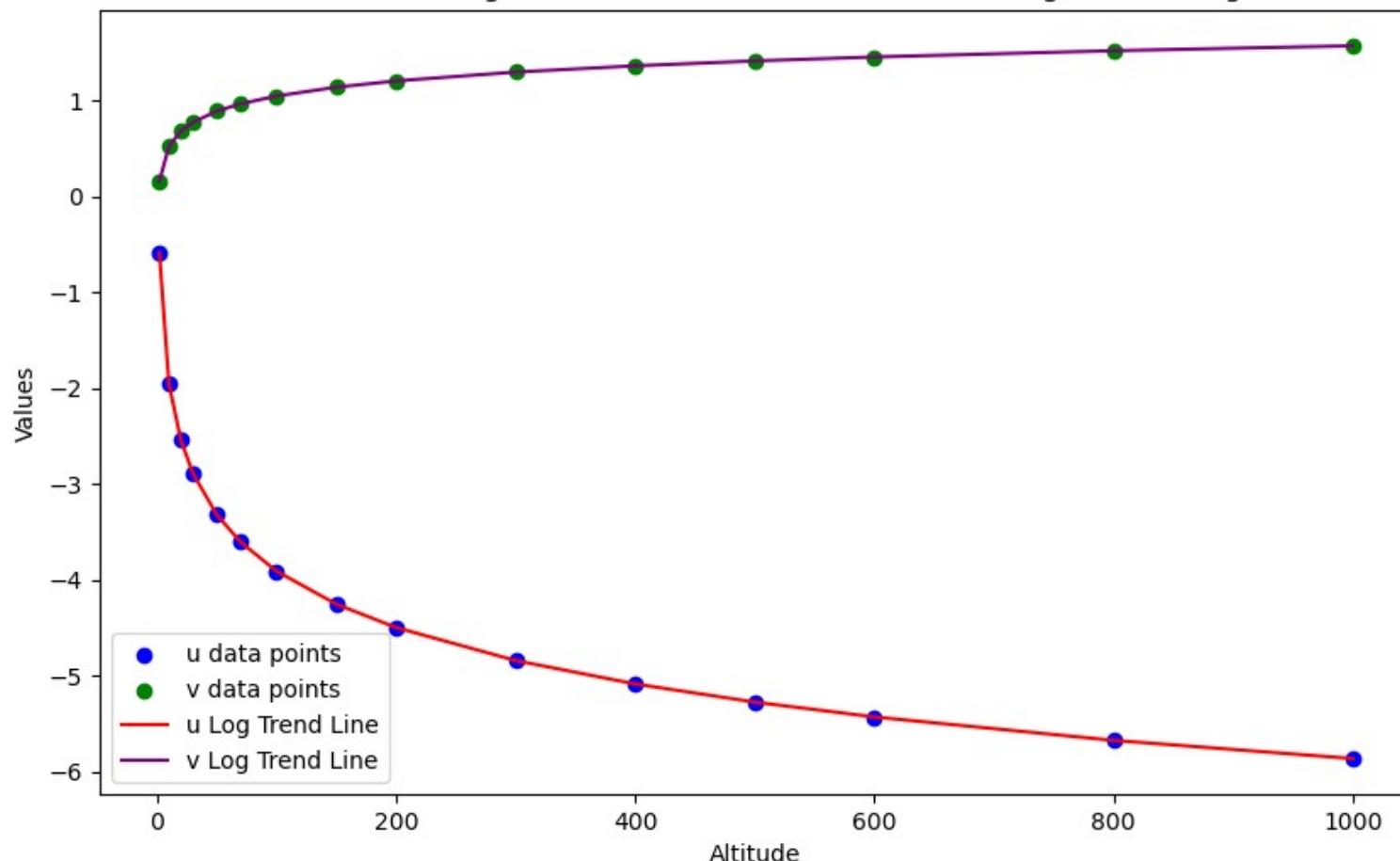


$$u = -0.85 * \log(\text{Altitude}) + -0.00$$

$$R^2 = 1.000$$

$$v = 0.23 * \log(\text{Altitude}) + -0.00$$

$R^2 = 1.000$ Scatter Plot with Logarithmic Trend Lines for u and v for Angle = 105 degrees

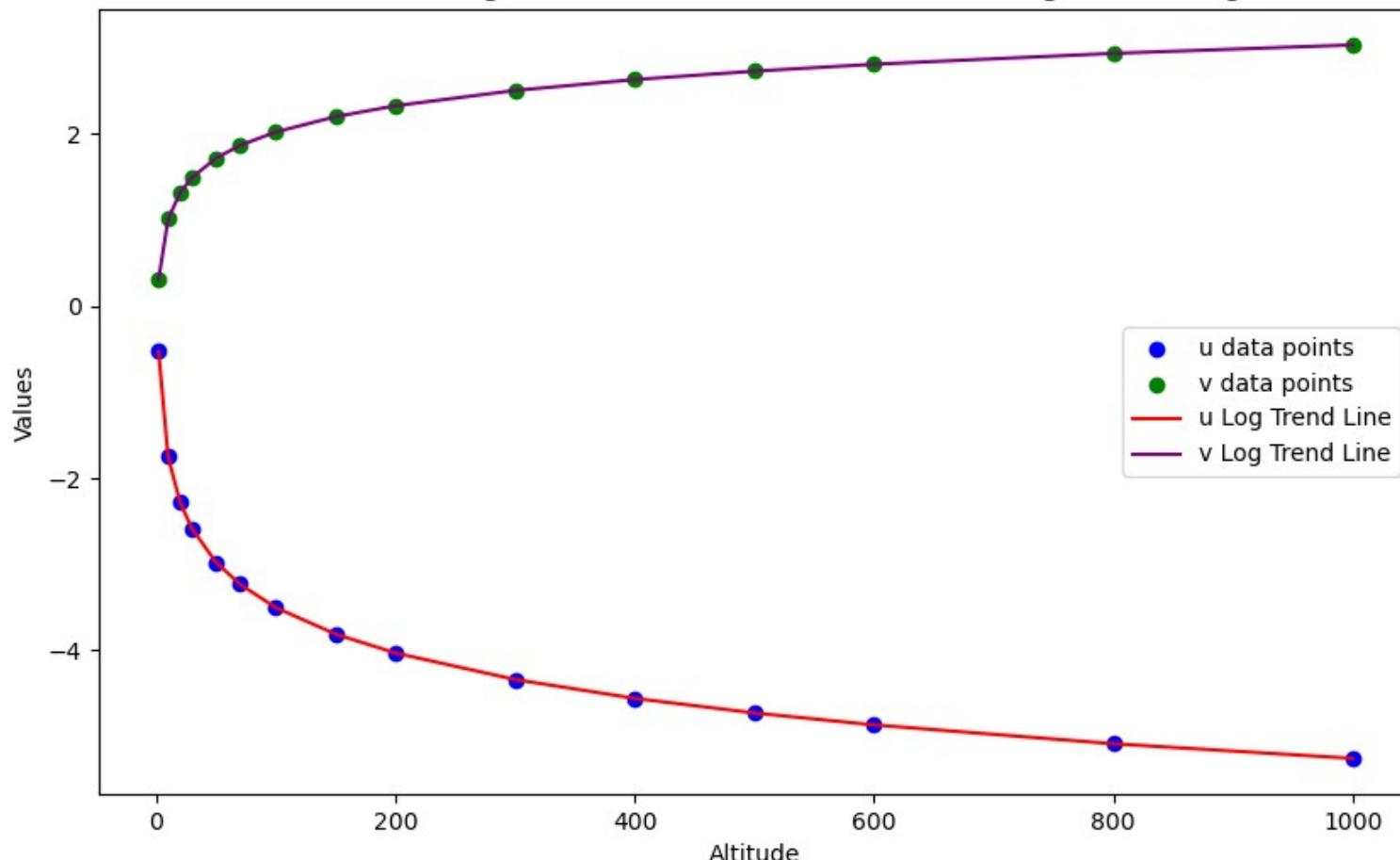


$$u = -0.76 * \log(\text{Altitude}) + 0.00$$

$$R^2 = 1.000$$

$$v = 0.44 * \log(\text{Altitude}) + 0.00$$

$R^2 = 1.000$ Scatter Plot with Logarithmic Trend Lines for u and v for Angle = 120 degrees

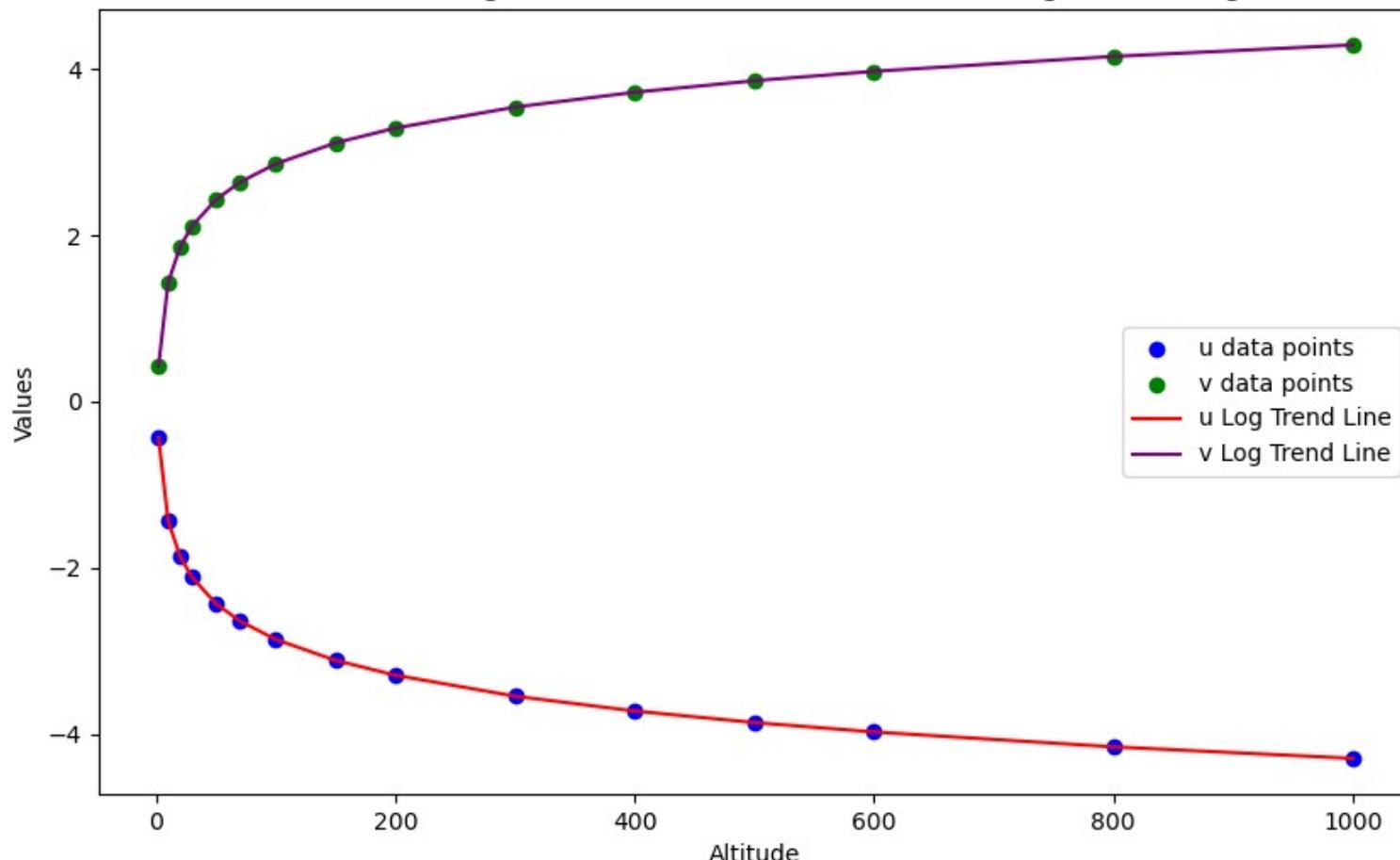


$$u = -0.62 * \log(\text{Altitude}) + 0.00$$

$$R^2 = 1.000$$

$$v = 0.62 * \log(\text{Altitude}) + -0.00$$

$R^2 = 1.000$ Scatter Plot with Logarithmic Trend Lines for u and v for Angle = 135 degrees

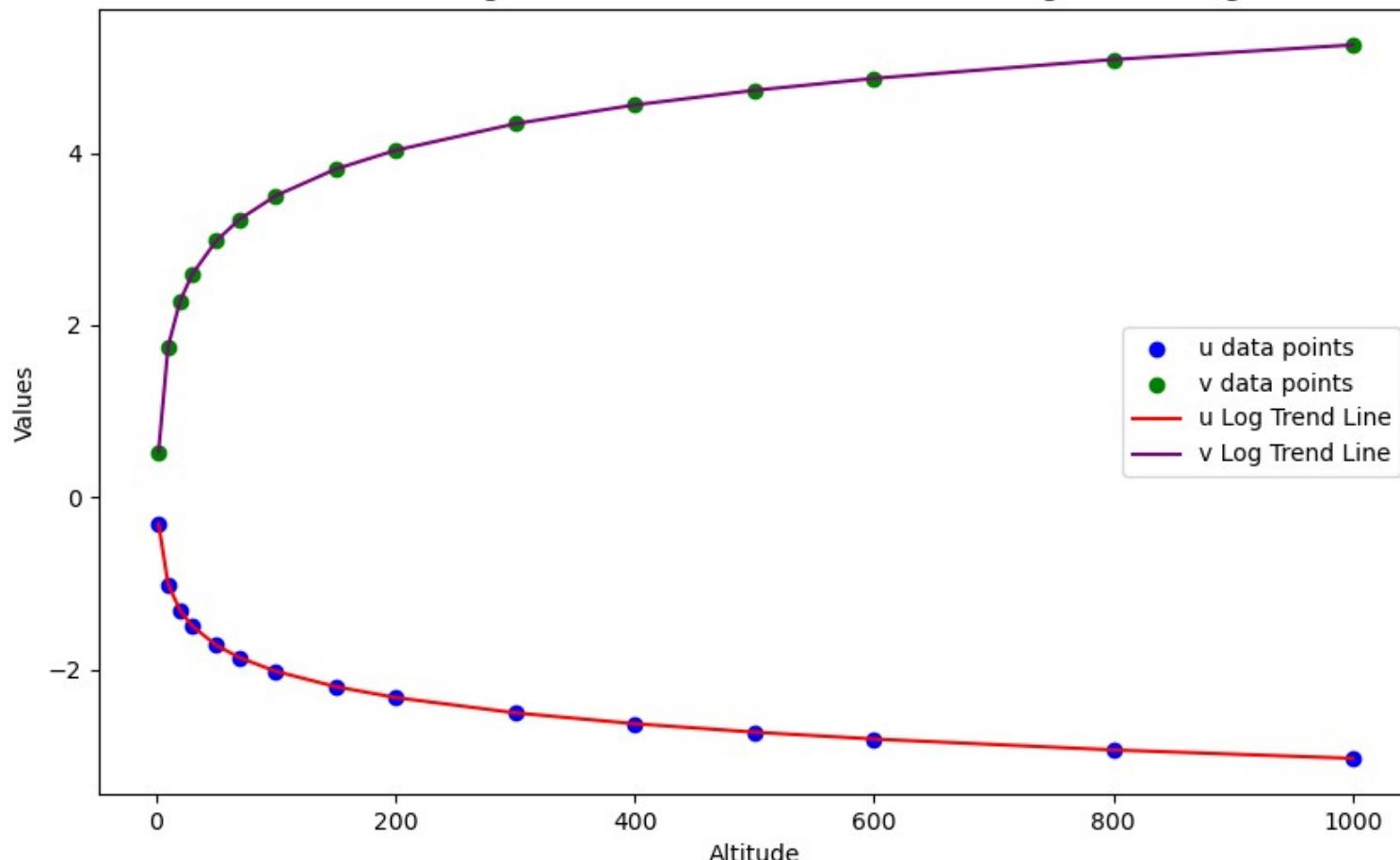


$$u = -0.44 * \log(\text{Altitude}) + -0.00$$

$$R^2 = 1.000$$

$$v = 0.76 * \log(\text{Altitude}) + -0.00$$

$R^2 = 1.000$ Scatter Plot with Logarithmic Trend Lines for u and v for Angle = 150 degrees

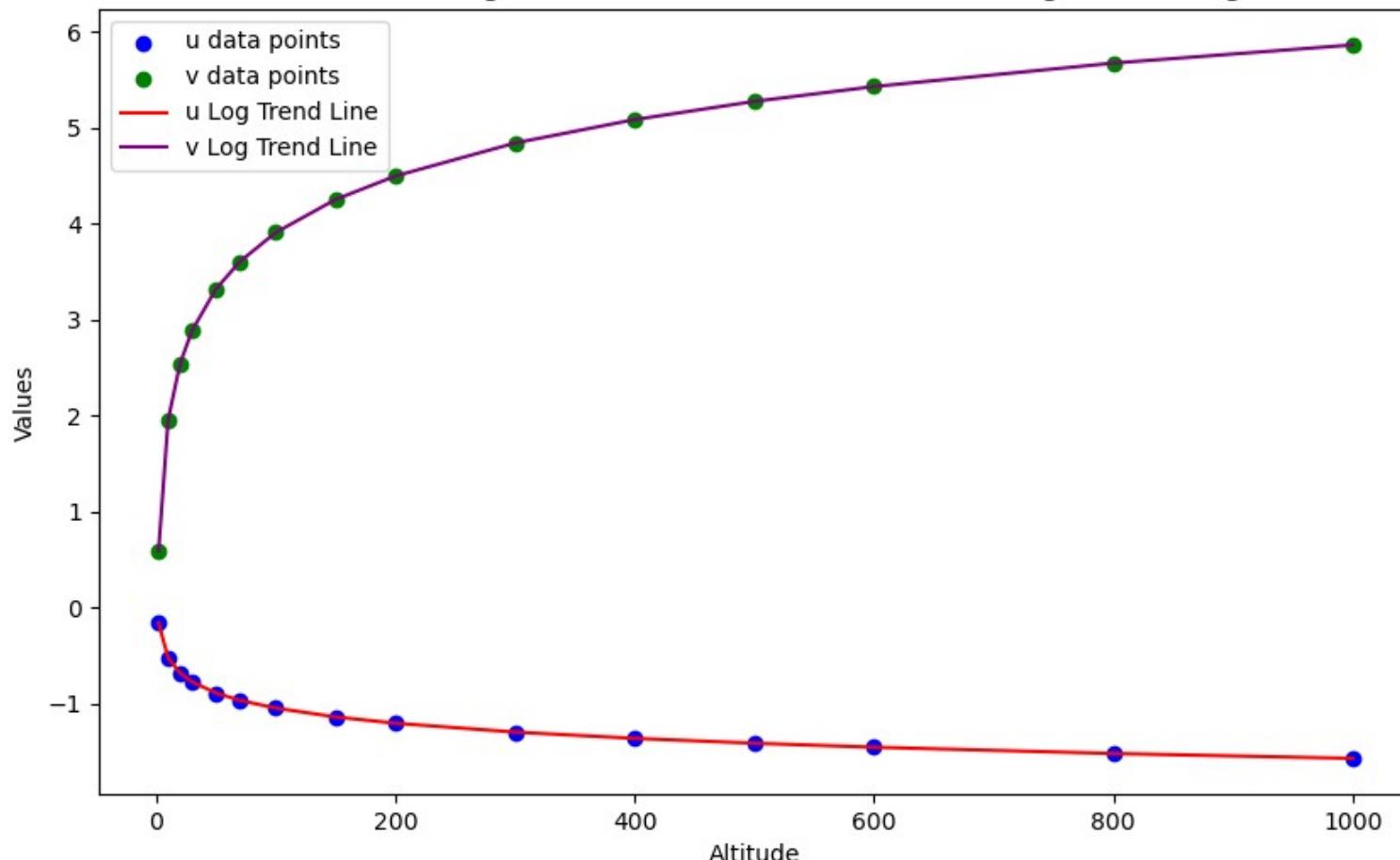


$$u = -0.23 * \log(\text{Altitude}) + 0.00$$

$$R^2 = 1.000$$

$$v = 0.85 * \log(\text{Altitude}) + 0.00$$

R² = 1.000 Scatter Plot with Logarithmic Trend Lines for u and v for Angle = 165 degrees

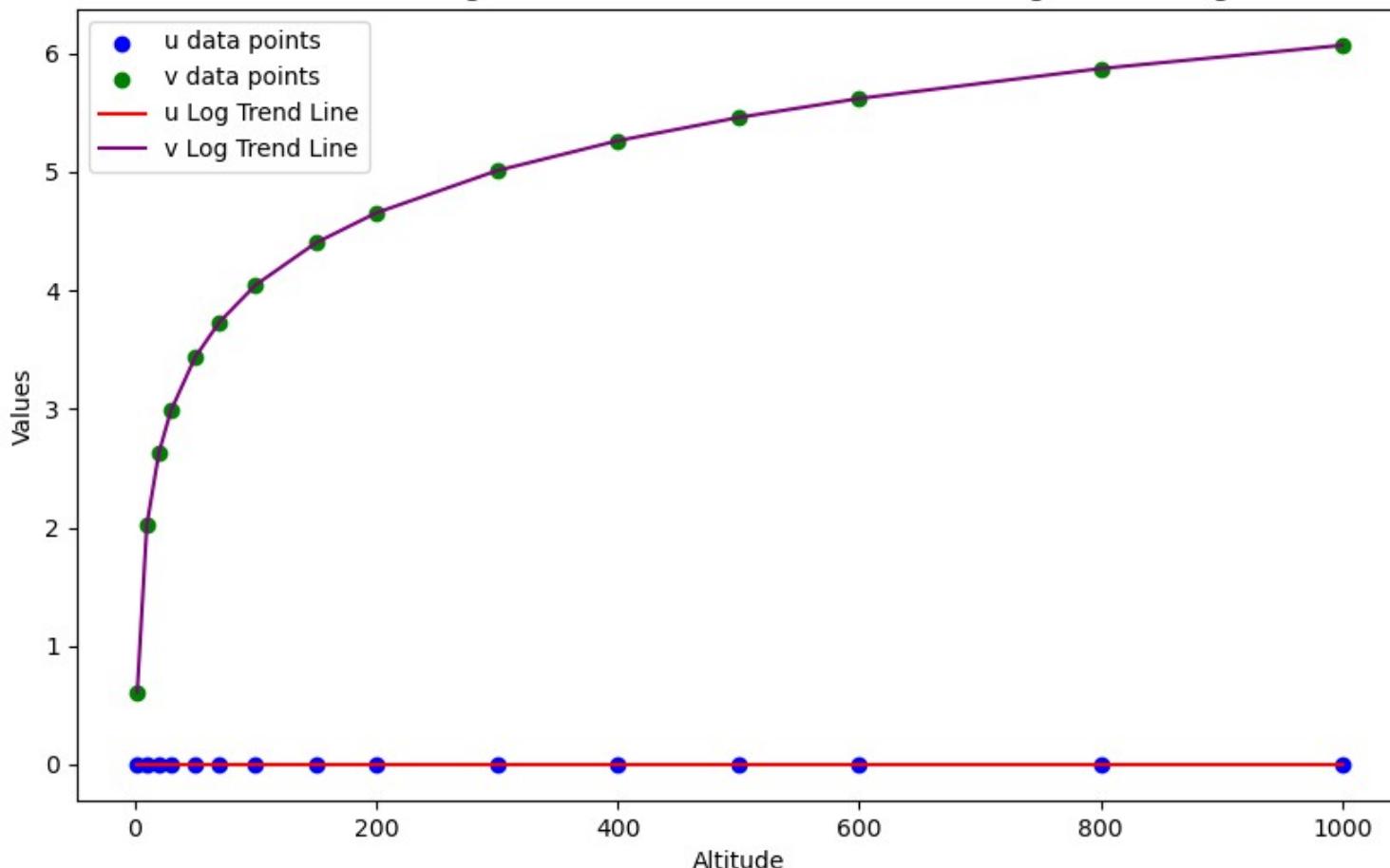


$u = 0.00 * \log(\text{Altitude}) + 0.00$

$R^2 = 0.000$

$v = 0.88 * \log(\text{Altitude}) + -0.00$

$R^2 = 1.000$ Scatter Plot with Logarithmic Trend Lines for u and v for Angle = 180 degrees



Scripts v4 – Preliminary Results

Some Parameters

Infinite epochs - instead the criteria for stopping is $\text{loss}_{\{n\}} - \text{loss}_{\{n-1\}} < \epsilon$ for 10 consecutive epochs where n is the epoch number and $\epsilon = 1E-5$ (user defined)

128 Neurons for the PINN unless otherwise specified

We have the data for 13 angles, [0, 15, 30, 45, 60, 75, 90, 105, 120, 135, 150, 165, 180] in degrees

We concatenate the data for angles = [0, 15, 30, 45, 60, 75, 90, 105, 120, 135, 150, 165, 180] and then take 99% of the dataset with random seed = 42 for training and 1% for testing

By using 99% of the whole dataset we hope to make the NN learn about wind angle such that the parameters become functions of the wind angle

Then using the trained neural network we predict the data for angle = 135

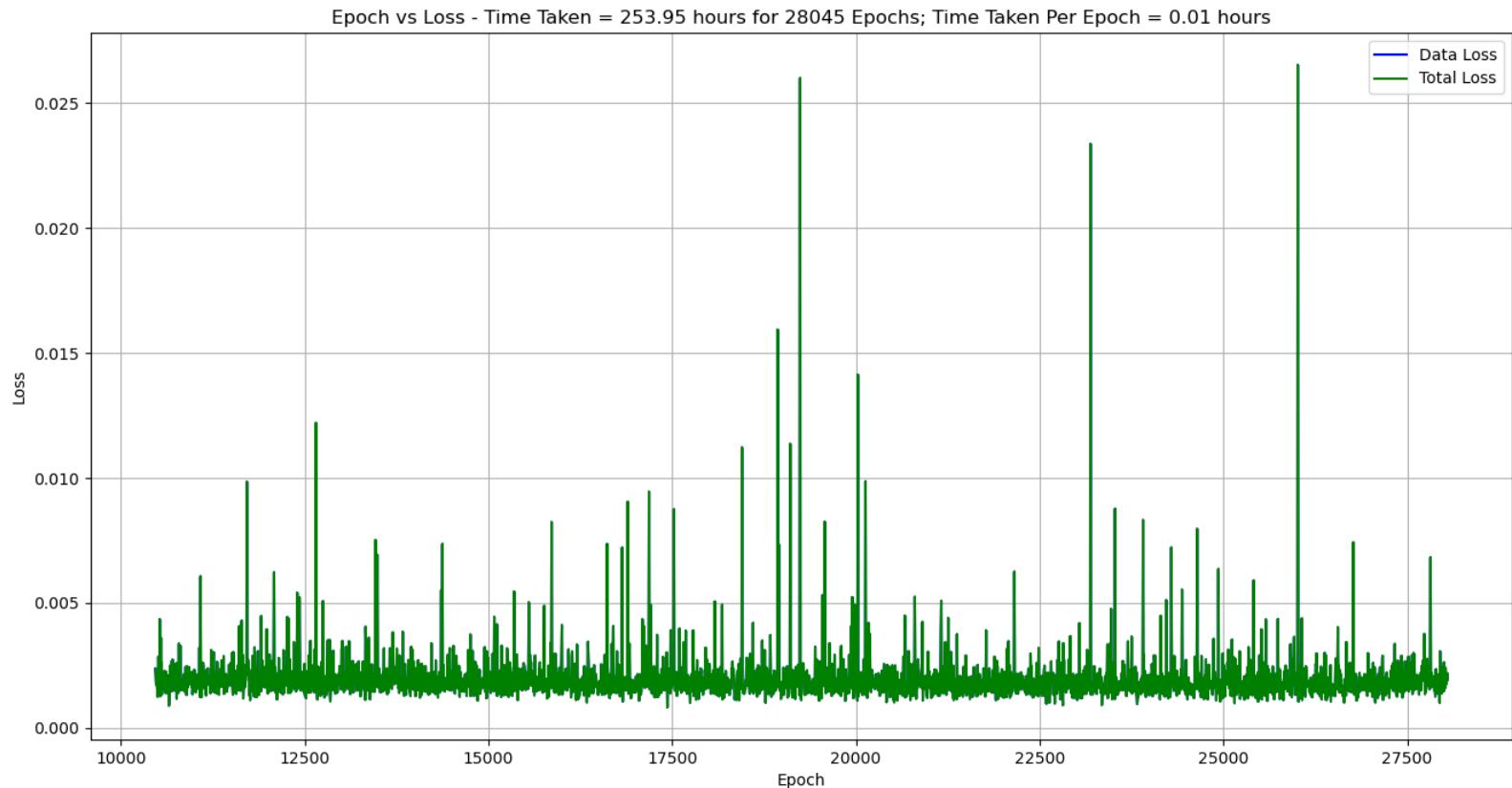
For this run, we will only have input parameters to be [X, Y, Z, $\cos(\theta)$, $\sin(\theta)$] and the output parameters will be [U, V, W]

Progress so far - Data Loss Only
Standard Normal Scalar
(Adam Optimizer)

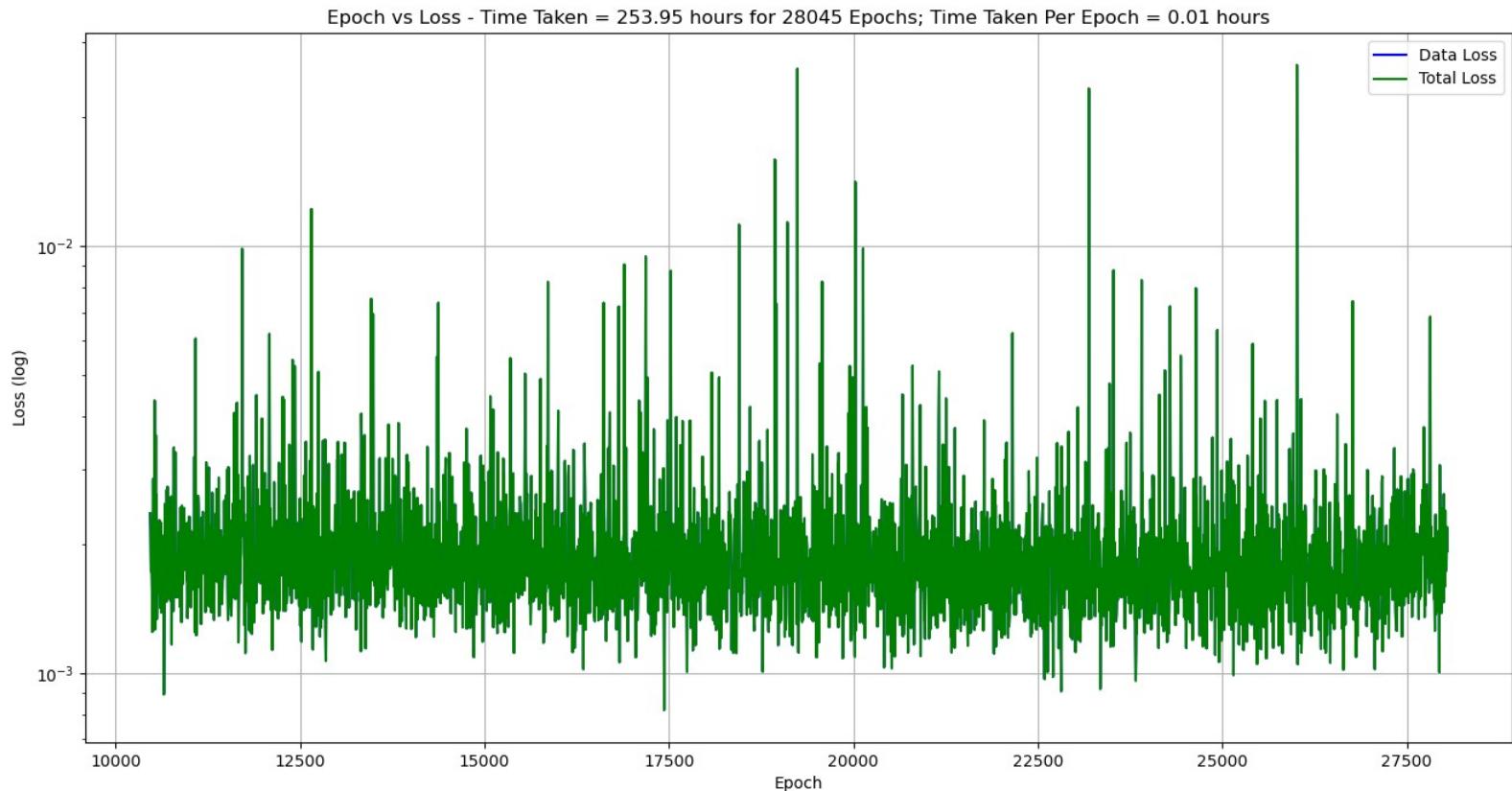
Threshold = 1E-5 (28405 Epochs, not completed), GPU Laptop

Scripts v4 – PREDICTING (135 DEG)

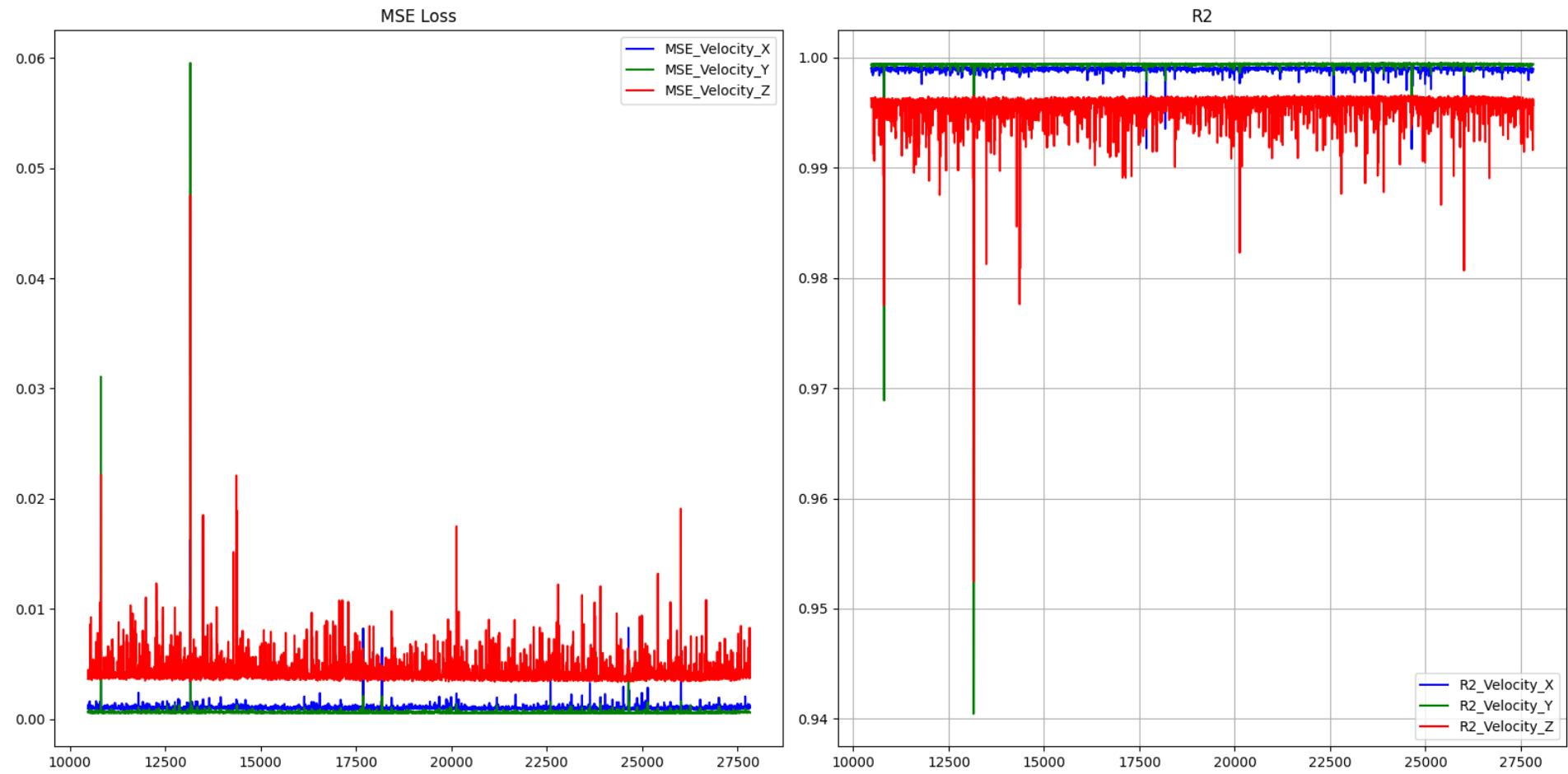
Progress so far - Data Loss Only (Adam Optimizer – Std Normal Scalar)
Logging Plots (Training)



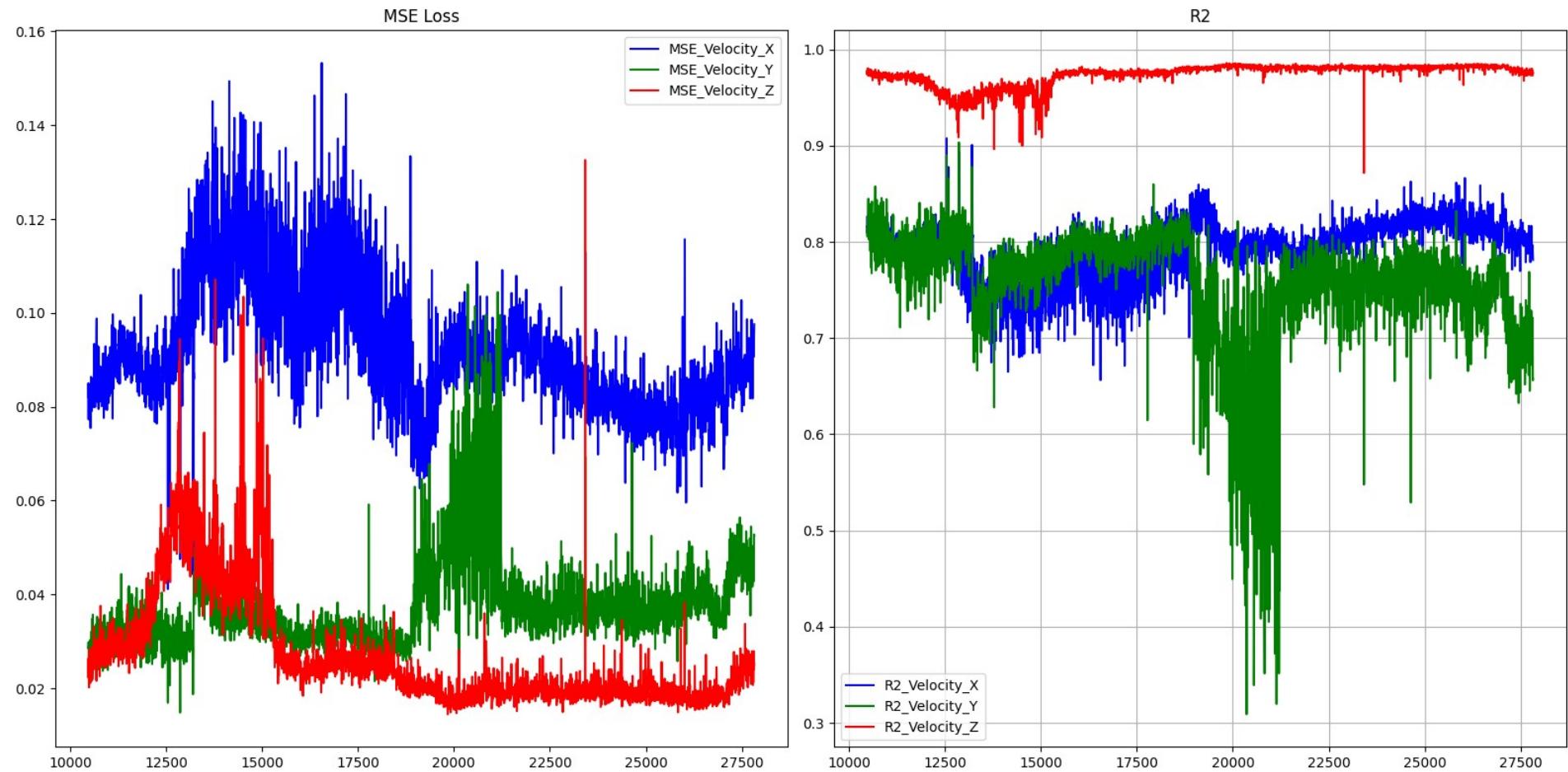
Progress so far - Data Loss Only (Adam Optimizer – Std Normal Scalar)
Logging Plots (Training)



Progress so far - Data Loss Only (Adam Optimizer – Std Normal Scalar)
Logging Plots (Testing)



Progress so far - Data Loss Only (Adam Optimizer – Std Normal Scalar)
Logging Plots (Predicting 135)



Progress so far - Data Loss Only (Adam Optimizer – Std Normal Scalar)
Threshold = 1E-5 (4900 Epochs, so far...), GPU Laptop
Predicting Results – Metrics (Angle = 135)

Variable	MSE	RMSE	MAE	R2
Velocity:0	0.308634757506756	0.55554905949588	0.464360776797406	0.697187485161744
Velocity:1	0.270307209787731	0.519910770986455	0.433073047598817	0.737320425082821
Velocity:2	0.00128996226831055	0.0359160447197426	0.0130729691069715	0.960568566914327

Progress so far - Data Loss Only (Adam Optimizer – Std Normal Scalar)
Threshold = 1E-5 (14505 Epochs, so far...), GPU Laptop
Predicting Results – Metrics (Angle = 135)

Variable	MSE	RMSE	MAE	R2
Velocity:0	0.250057728211143	0.500057724878981	0.413546267613177	0.754659487654433
Velocity:1	0.247255388675443	0.497247814148482	0.412825970825431	0.759721760865162
Velocity:2	0.0014839236719385	0.0385217298669016	0.0149620490506694	0.954639574806382

Progress so far - Data Loss Only (Adam Optimizer – Std Normal Scalar)
Threshold = 1E-5 (24975 Epochs, so far...), GPU Laptop
Predicting Results – Metrics (Angle = 135)

Variable	MSE	RMSE	MAE	R2
Velocity:0	0.169371442348882	0.411547618567866	0.346039840856076	0.833823666479545
Velocity:1	0.250989906362938	0.50098892838359	0.413779126370932	0.756092625262593
Velocity:2	0.0005541080895412 14	0.0235395006221715	0.0115606431933764	0.98306208127809

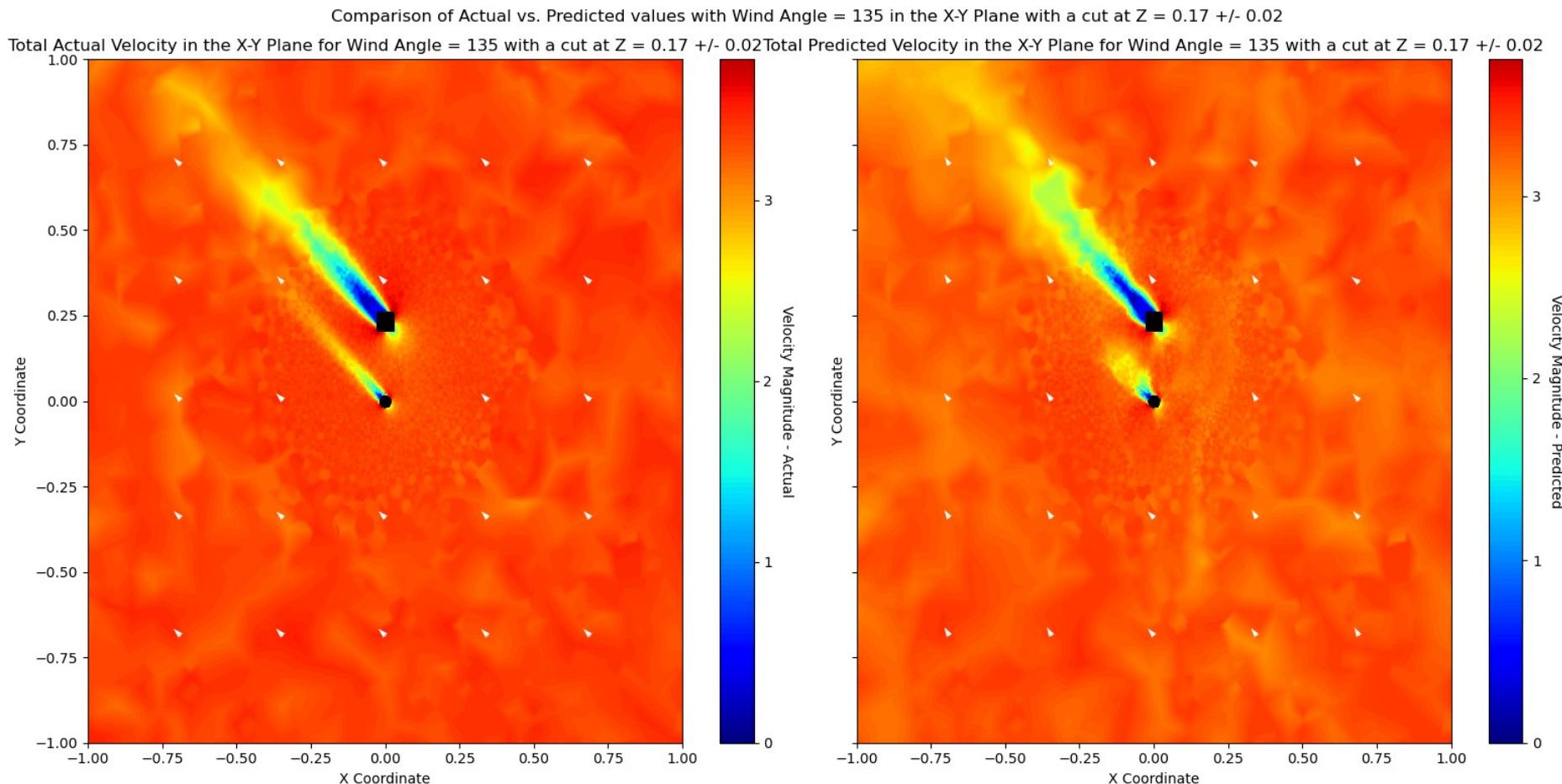
Progress so far - Data Loss Only (Adam Optimizer – Std Normal Scalar)
Threshold = 1E-5 (26180 Epochs, so far...), GPU Laptop
Predicting Results – Metrics (Angle = 135)

Variable	MSE	RMSE	MAE	R2
Velocity:0	0.161648488044868	0.402055329581475	0.342505231151627	0.8414009310549
Velocity:1	0.258453147637316	0.508382875043324	0.418237896632697	0.748839984657862
Velocity:2	0.0005524698251586 7	0.0235046766656908	0.0121170744285219	0.983112159574149

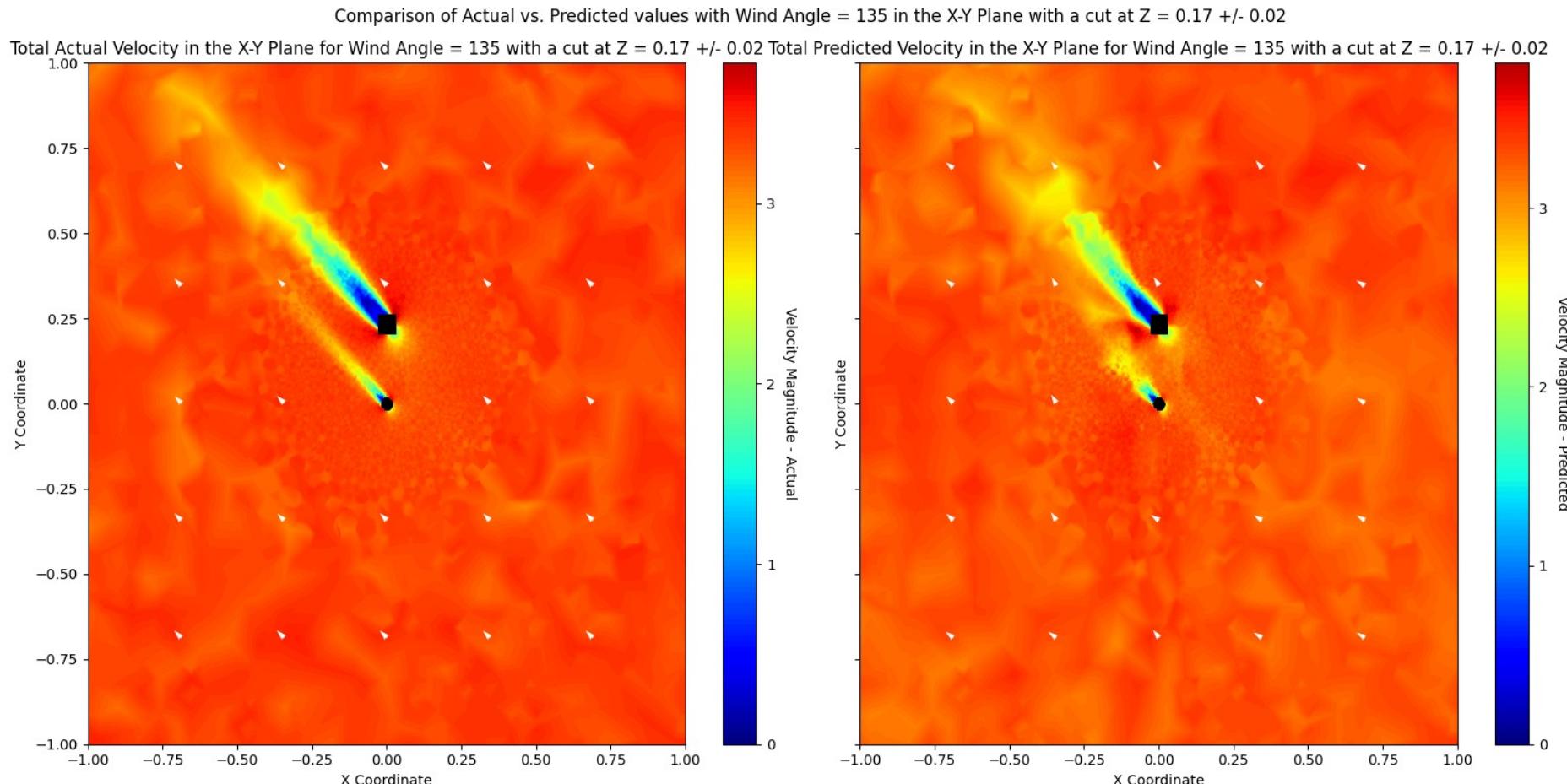
Progress so far - Data Loss Only (Adam Optimizer – Std Normal Scalar)
Threshold = 1E-5 (27030 Epochs, so far...), GPU Laptop
Predicting Results – Metrics (Angle = 135)

Variable	MSE	RMSE	MAE	R2
Velocity:0	0.152442372797009	0.390438692750871	0.334125631982556	0.850433377473492
Velocity:1	0.24776353577557	0.497758511504896	0.419178732510625	0.759227952859221
Velocity:2	0.0005320120898521 75	0.0230653872686364	0.0122115938862961	0.98373750950929

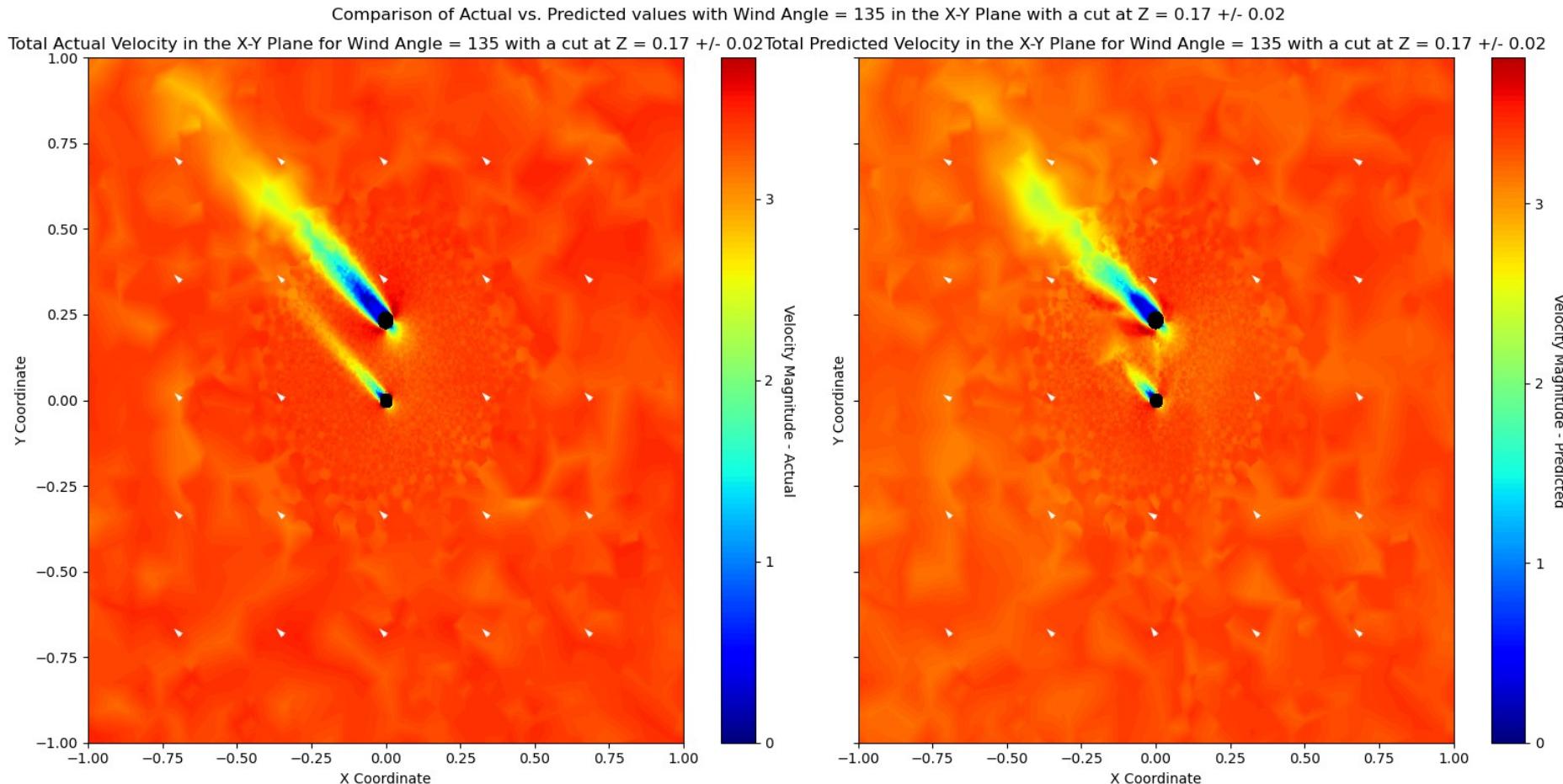
Progress so far - Data Loss Only (Adam Optimizer – Std Normal Scalar), Threshold = 1E-5 (4900 Epochs, so far...), GPU Laptop
Predicting Results - X-Y Total Velocity Plot (Angle = 135)



Progress so far - Data Loss Only (Adam Optimizer – Std Normal Scalar), Threshold = 1E-5 (14505 Epochs, so far...), GPU Laptop
Predicting Results - X-Y Total Velocity Plot (Angle = 135)

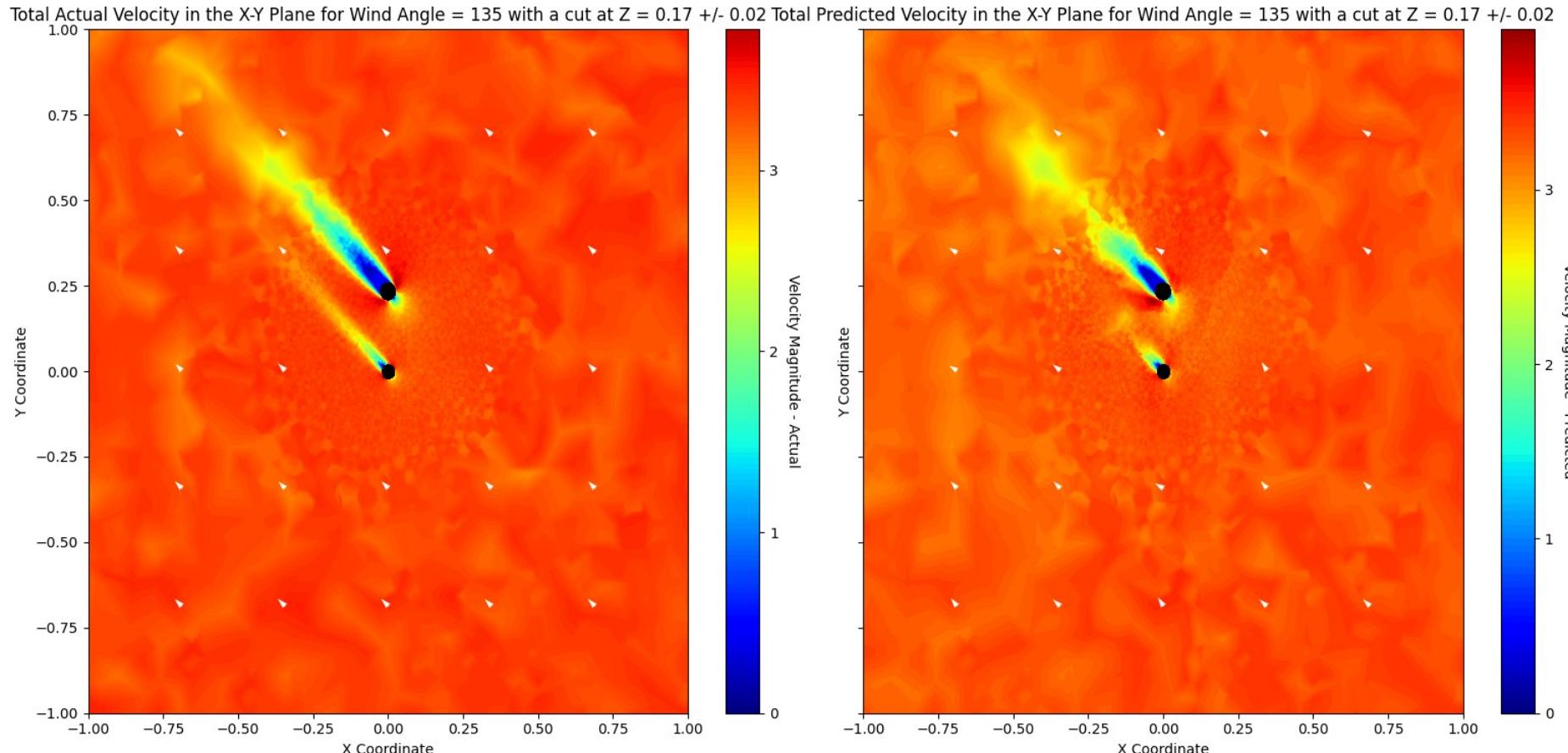


Progress so far - Data Loss Only (Adam Optimizer – Std Normal Scalar), Threshold = 1E-5 (24975 Epochs, so far...), GPU Laptop
Predicting Results - X-Y Total Velocity Plot (Angle = 135)

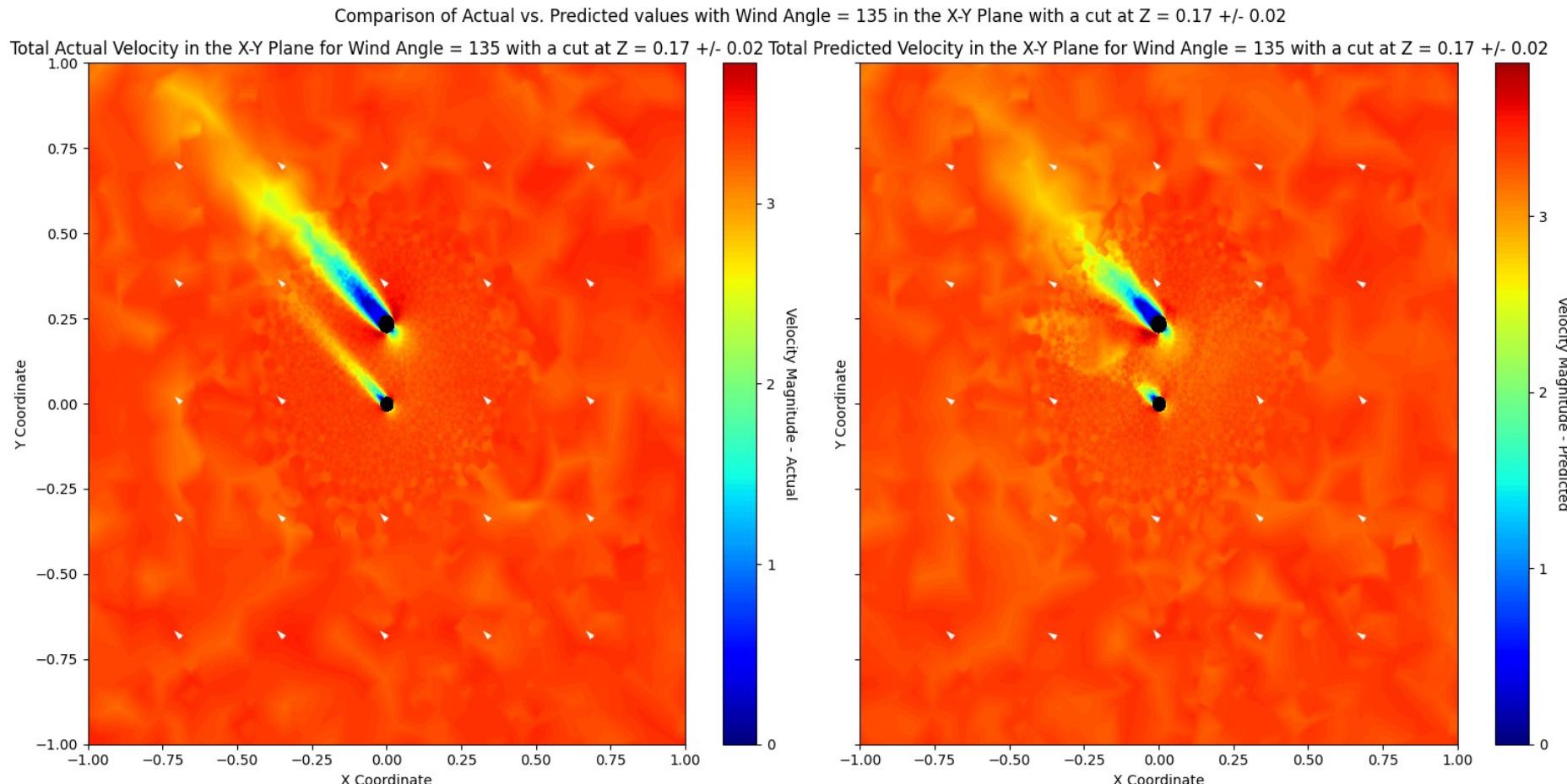


Progress so far - Data Loss Only (Adam Optimizer – Std Normal Scalar), Threshold = 1E-5 (26180 Epochs, so far...), GPU Laptop
Predicting Results - X-Y Total Velocity Plot (Angle = 135)

Comparison of Actual vs. Predicted values with Wind Angle = 135 in the X-Y Plane with a cut at Z = 0.17 +/- 0.02



Progress so far - Data Loss Only (Adam Optimizer – Std Normal Scalar), Threshold = 1E-5 (27030 Epochs, so far...), GPU Laptop
Predicting Results - X-Y Total Velocity Plot (Angle = 135)

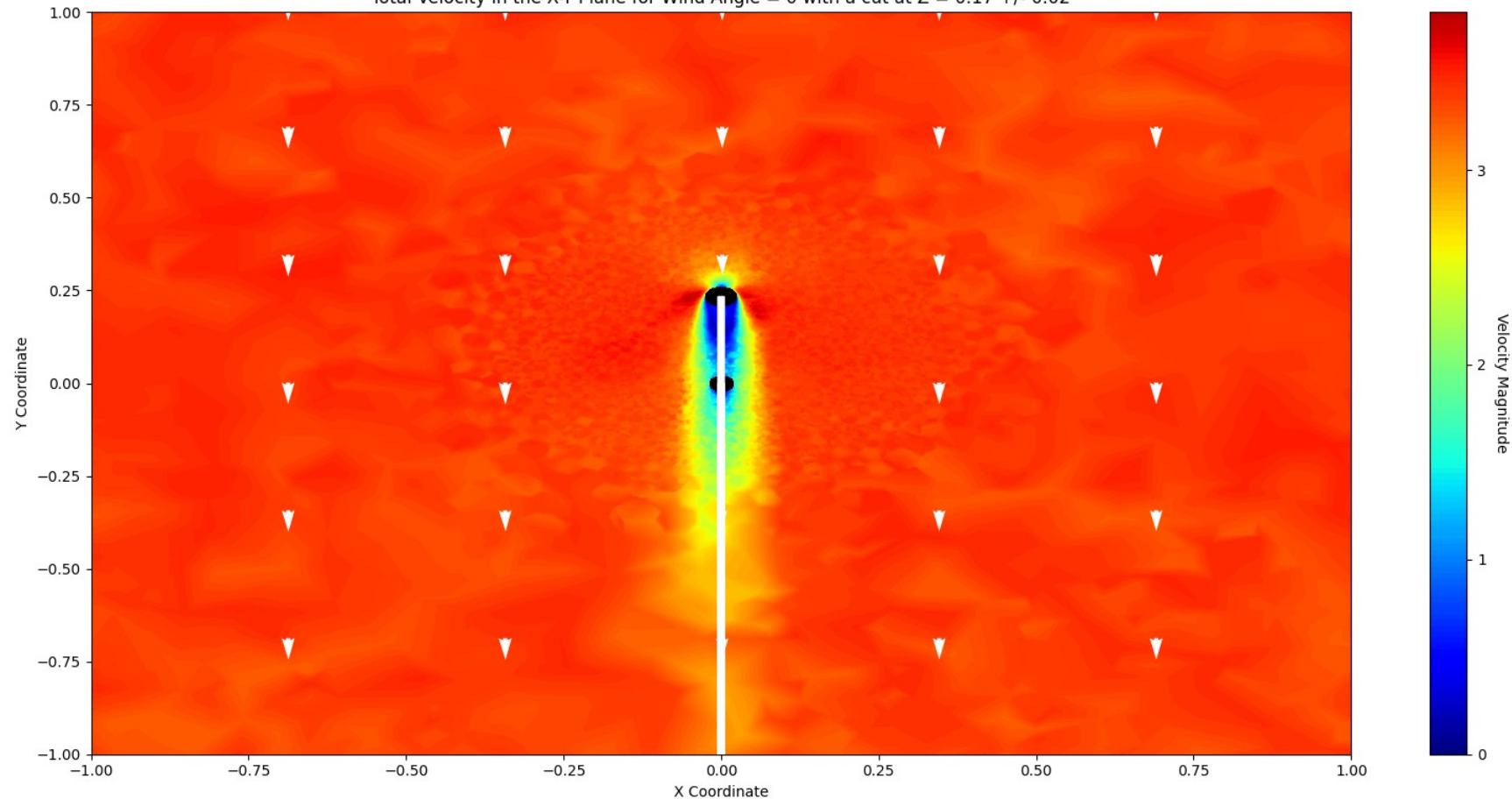


Progress so far - Data Loss Only
Standard Normal Scalar
(Adam Optimizer)

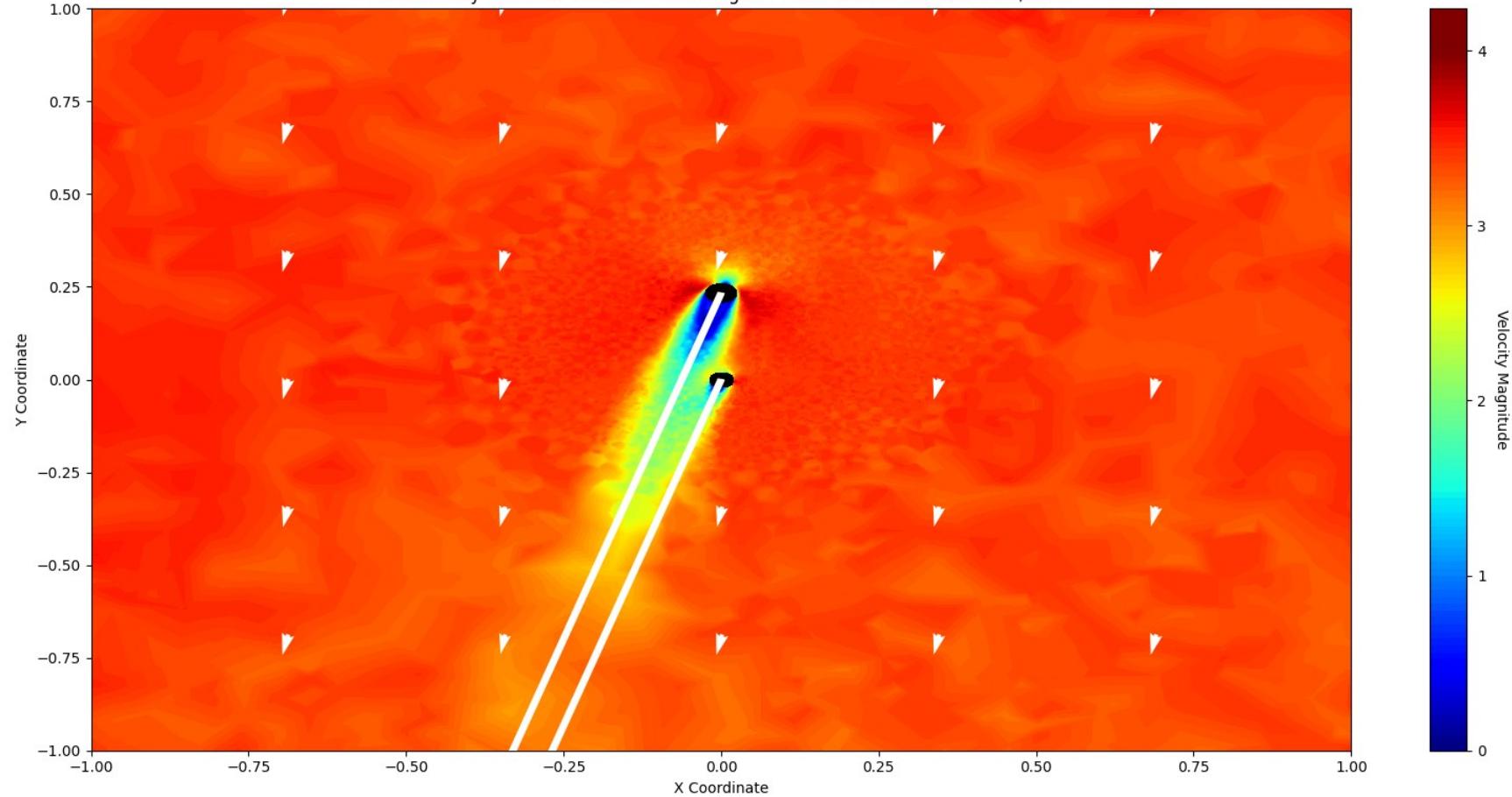
Threshold = 1E-5 (26180 Epochs, not completed), GPU Laptop

Scripts v4 – Plotting Any Angle

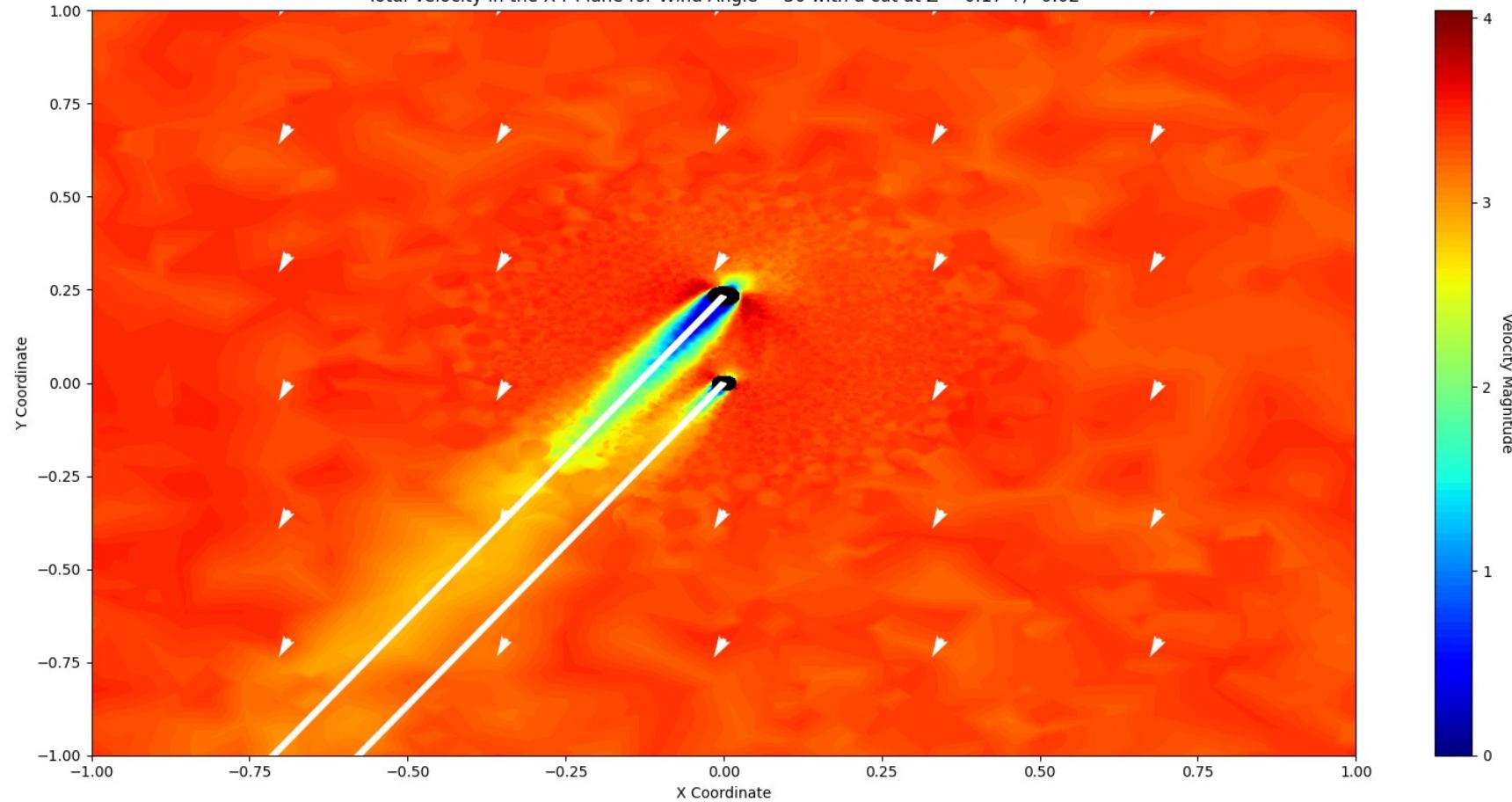
Total Velocity in the X-Y Plane for Wind Angle = 0 with a cut at Z = 0.17 +/- 0.02



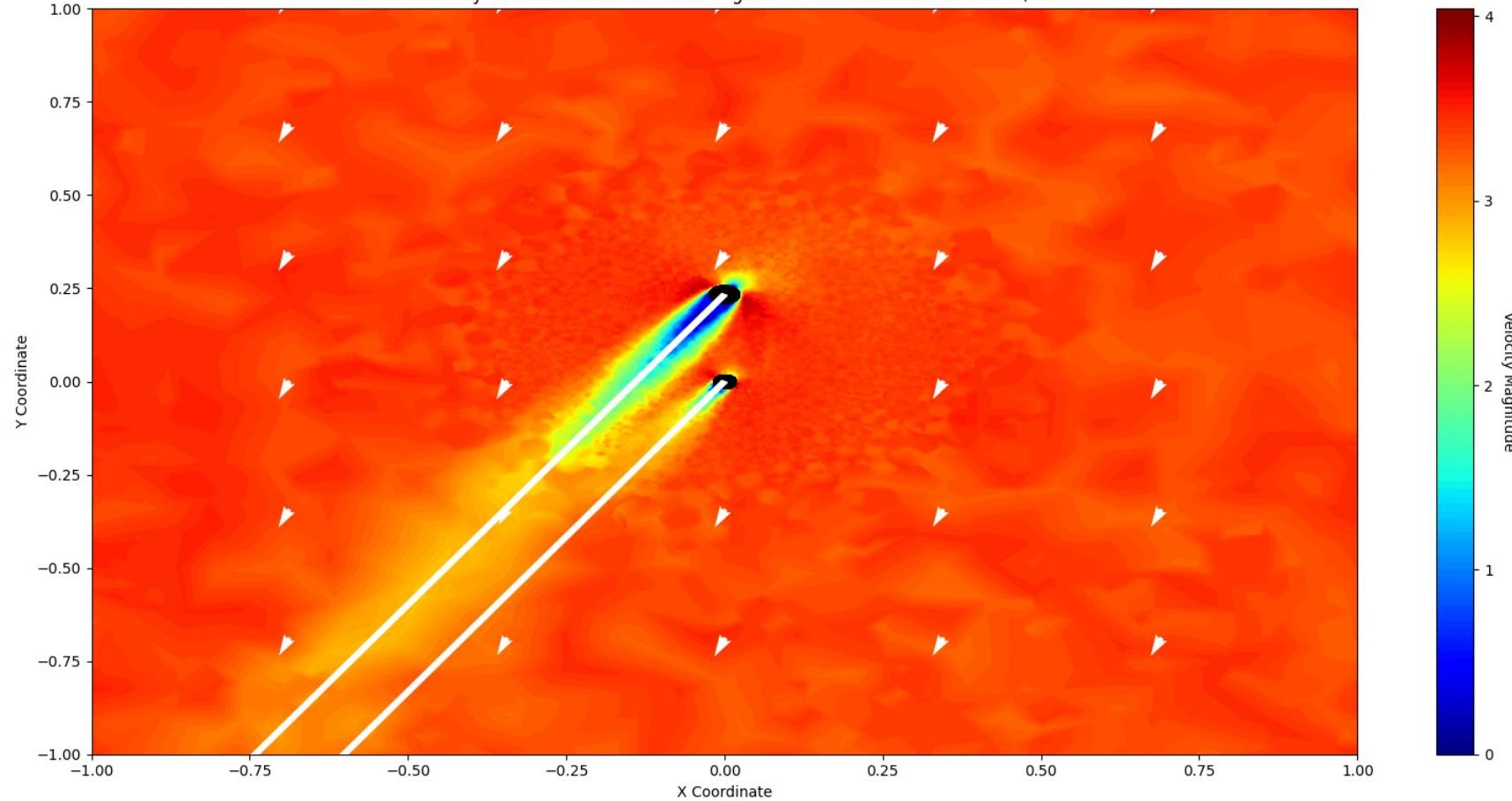
Total Velocity in the X-Y Plane for Wind Angle = 15 with a cut at Z = 0.17 +/- 0.02



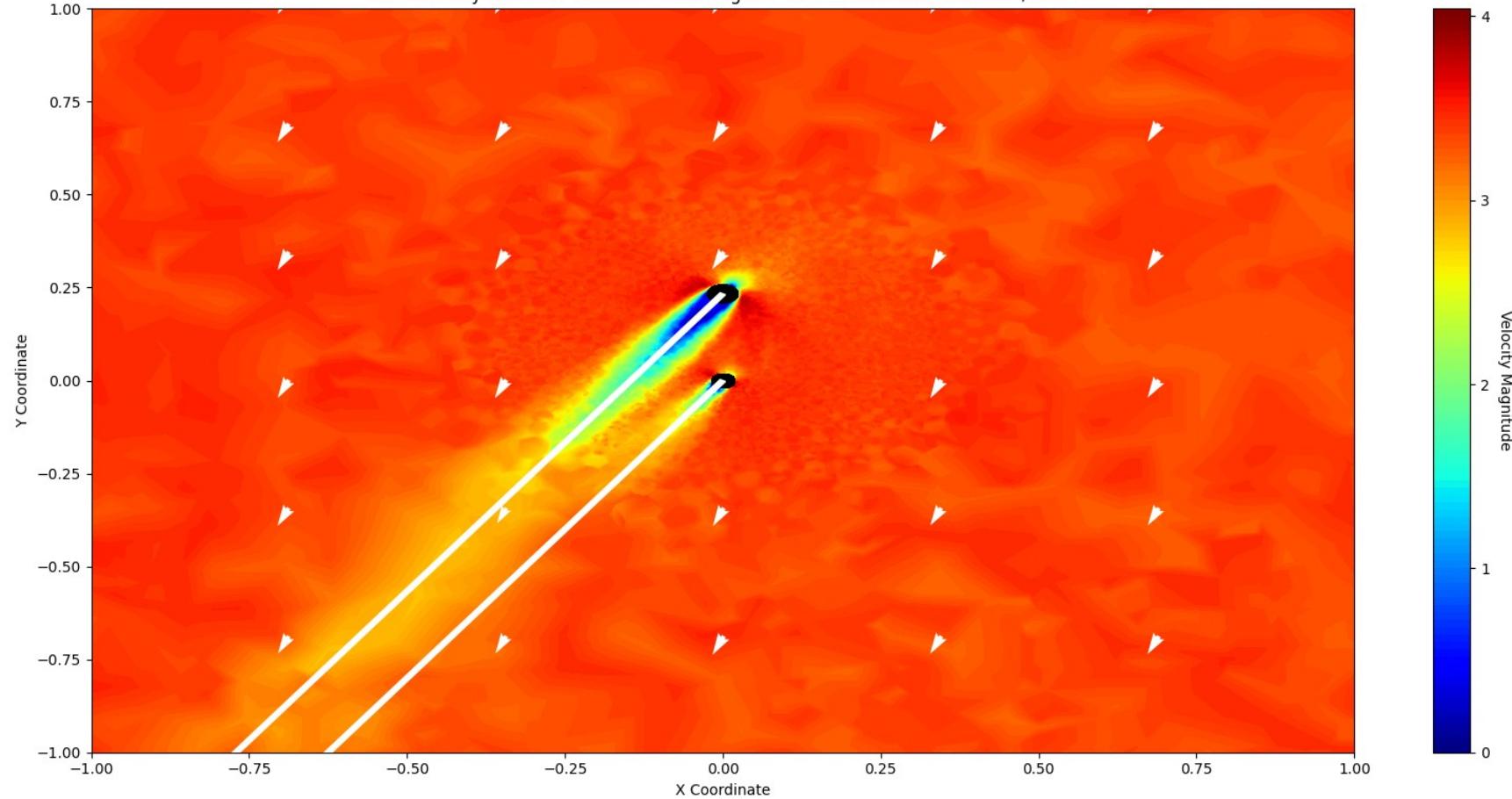
Total Velocity in the X-Y Plane for Wind Angle = 30 with a cut at Z = 0.17 +/- 0.02



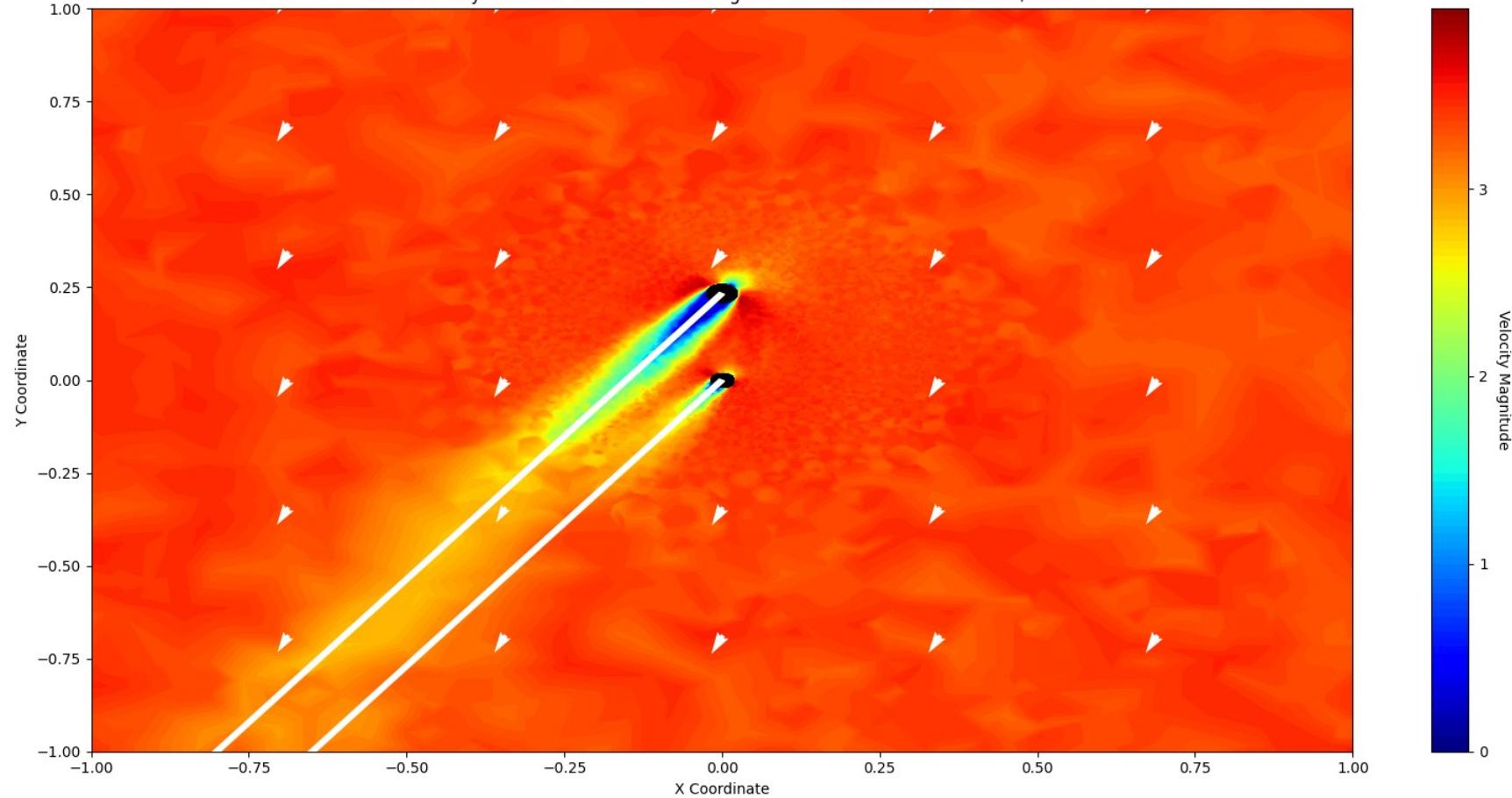
Total Velocity in the X-Y Plane for Wind Angle = 31 with a cut at Z = 0.17 +/- 0.02



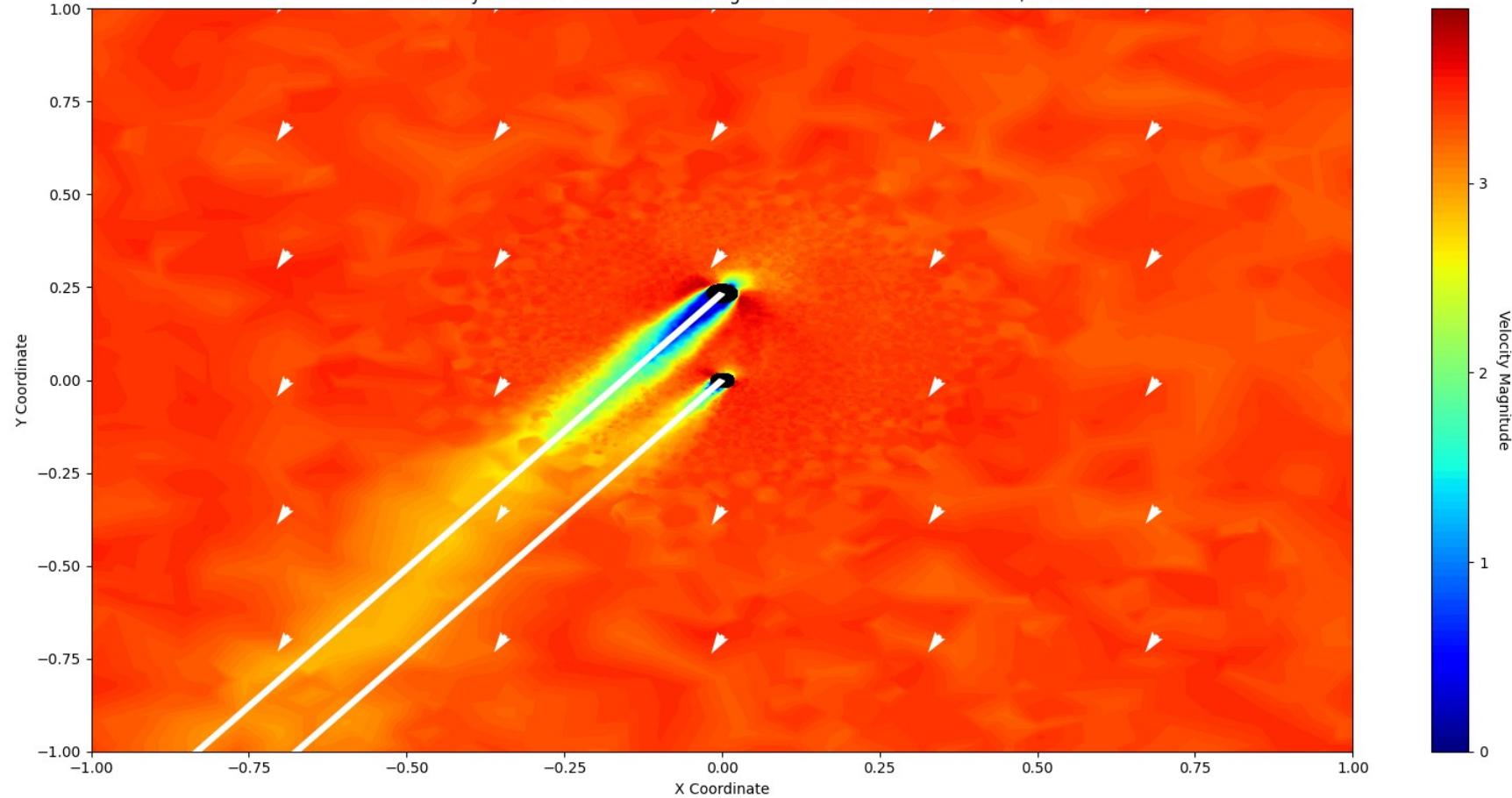
Total Velocity in the X-Y Plane for Wind Angle = 32 with a cut at Z = 0.17 +/- 0.02



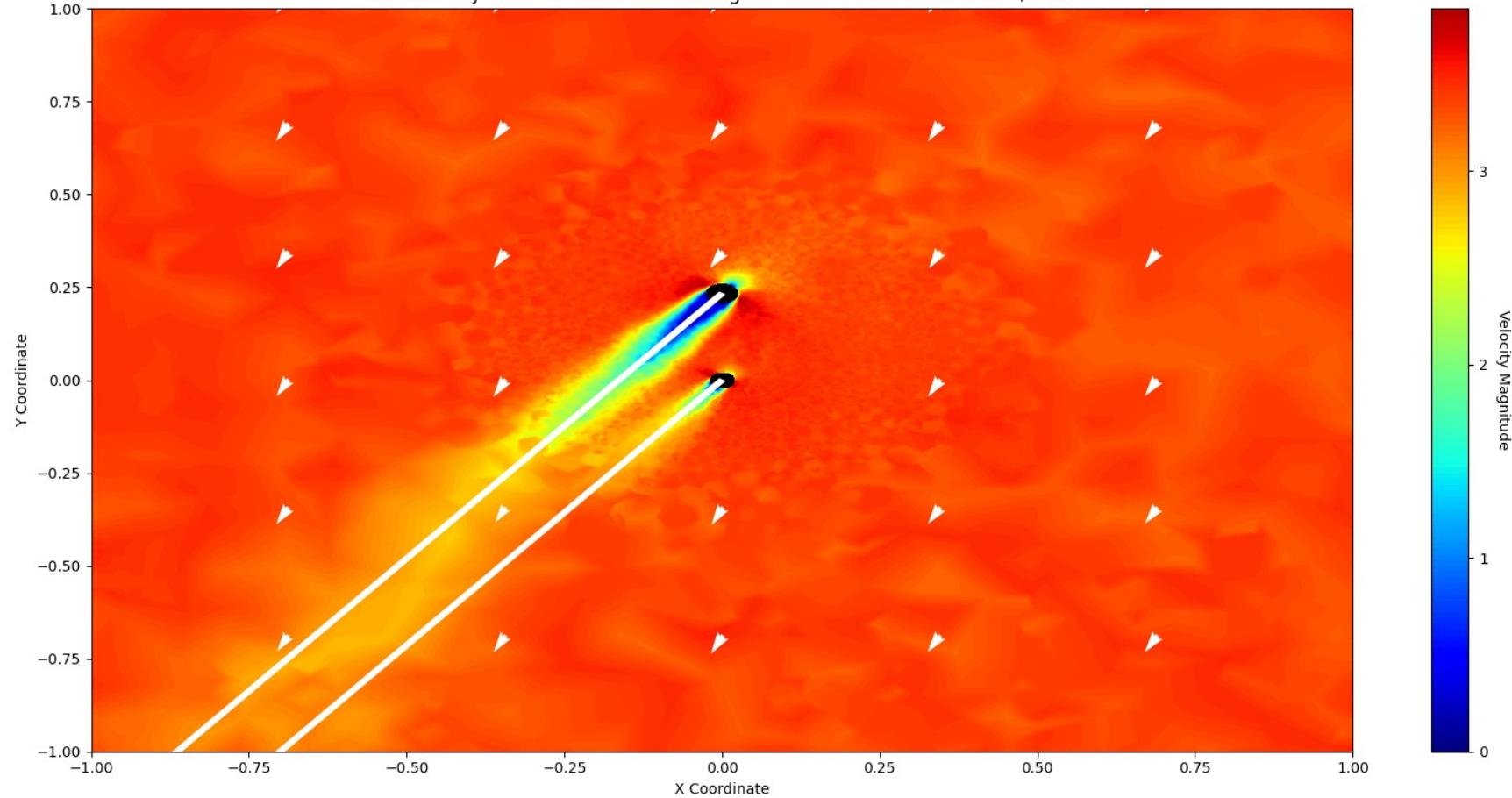
Total Velocity in the X-Y Plane for Wind Angle = 33 with a cut at Z = 0.17 +/- 0.02



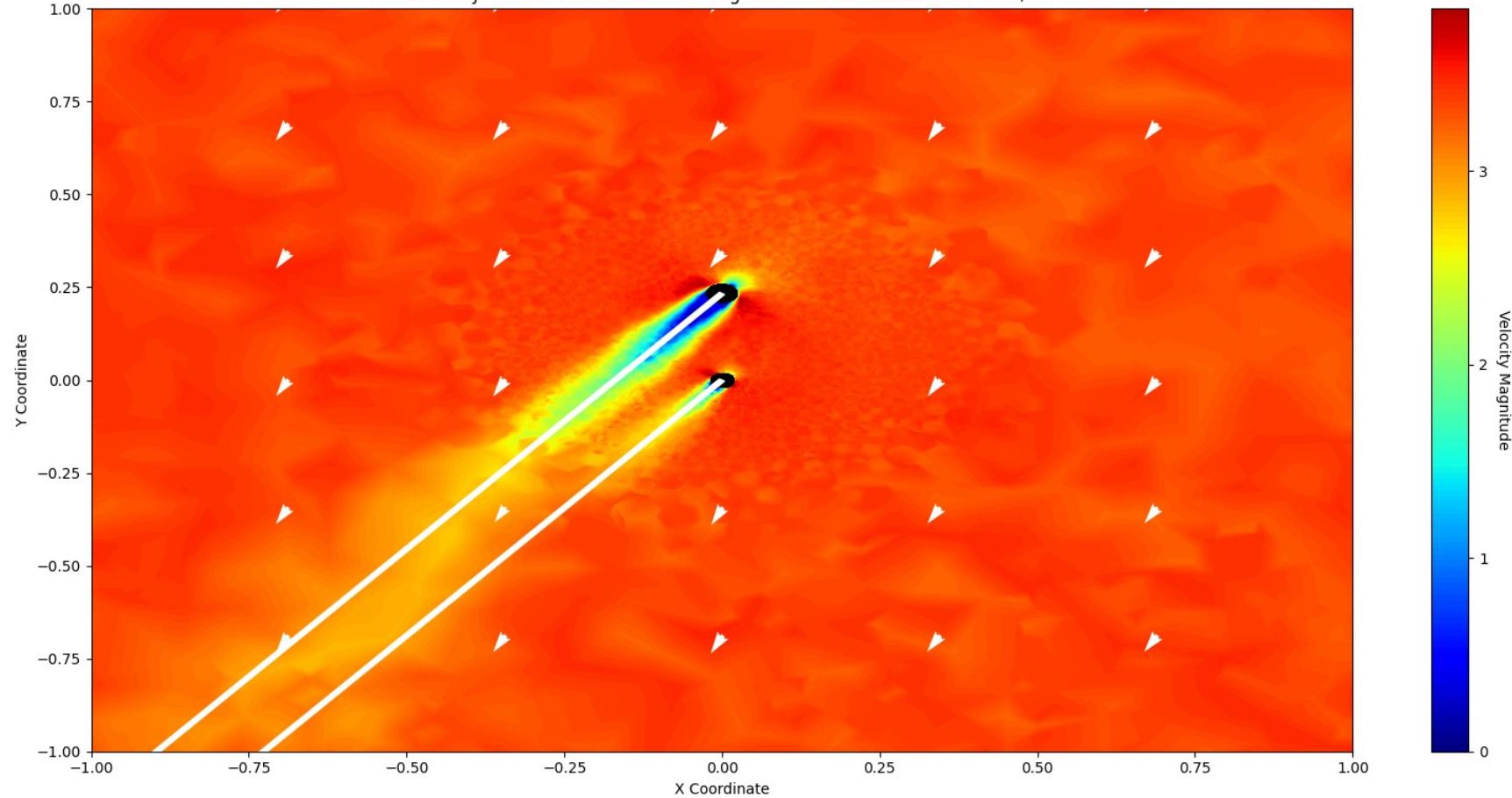
Total Velocity in the X-Y Plane for Wind Angle = 34 with a cut at Z = 0.17 +/- 0.02



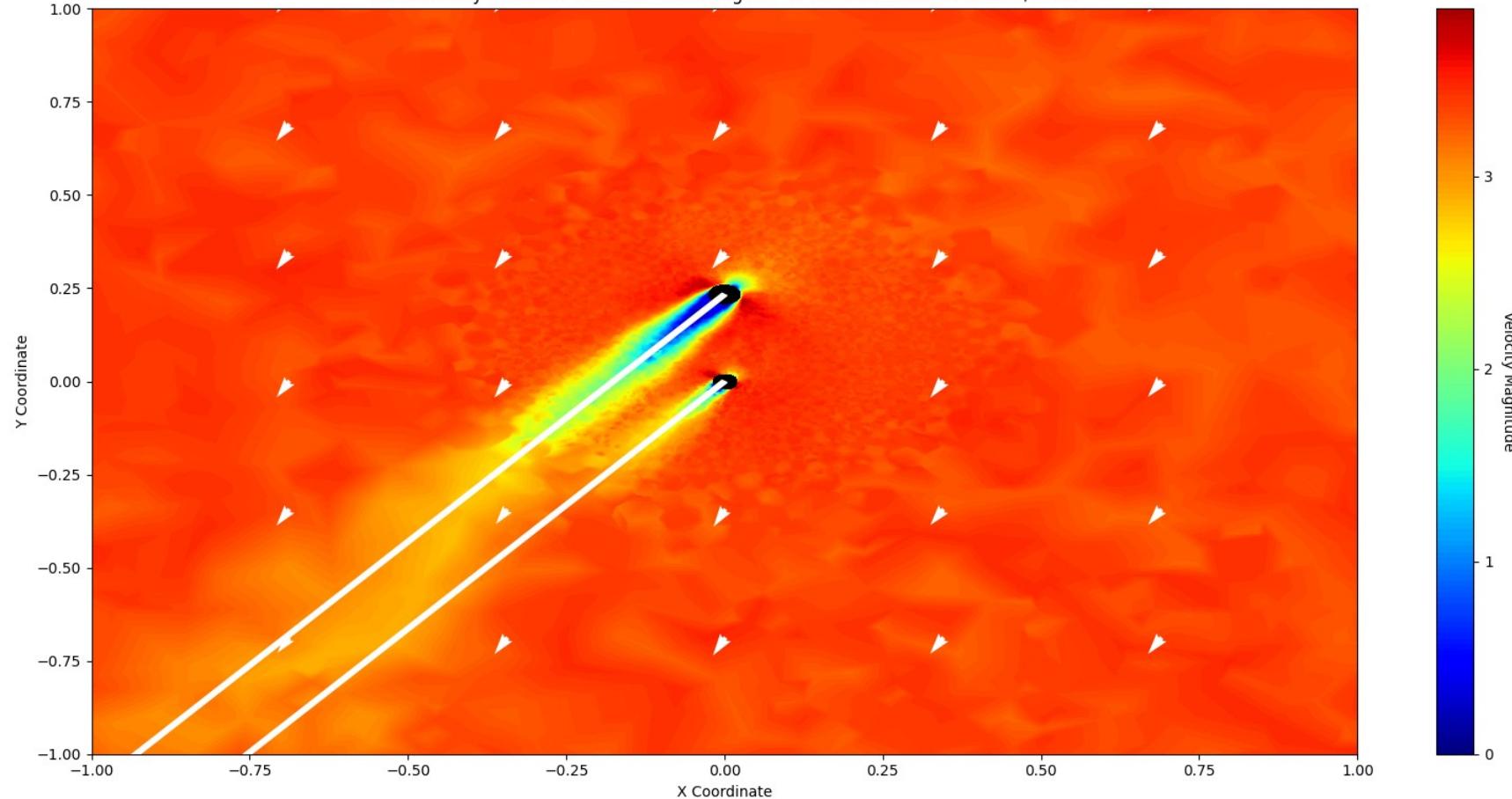
Total Velocity in the X-Y Plane for Wind Angle = 35 with a cut at Z = 0.17 +/- 0.02



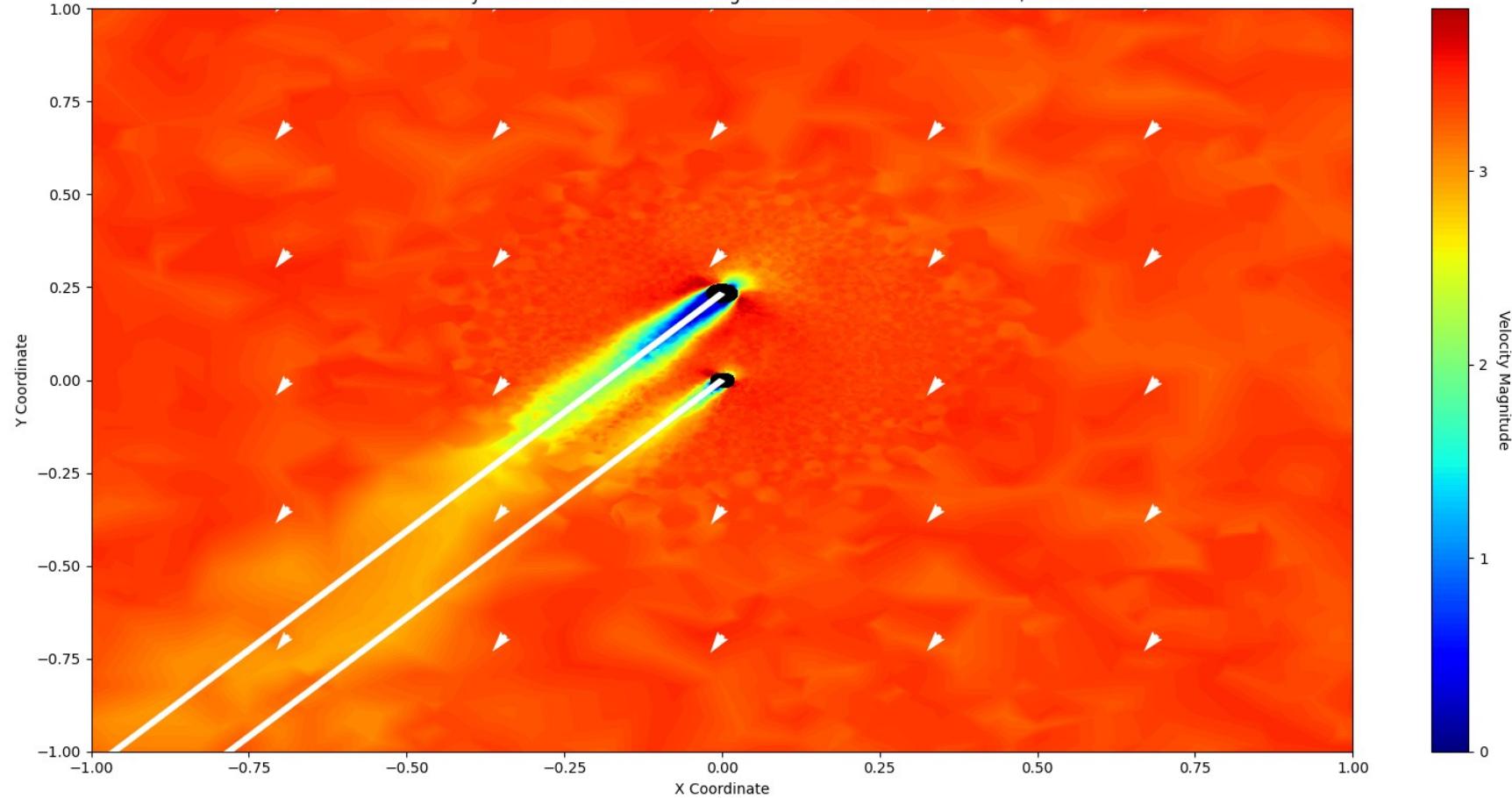
Total Velocity in the X-Y Plane for Wind Angle = 36 with a cut at Z = 0.17 +/- 0.02



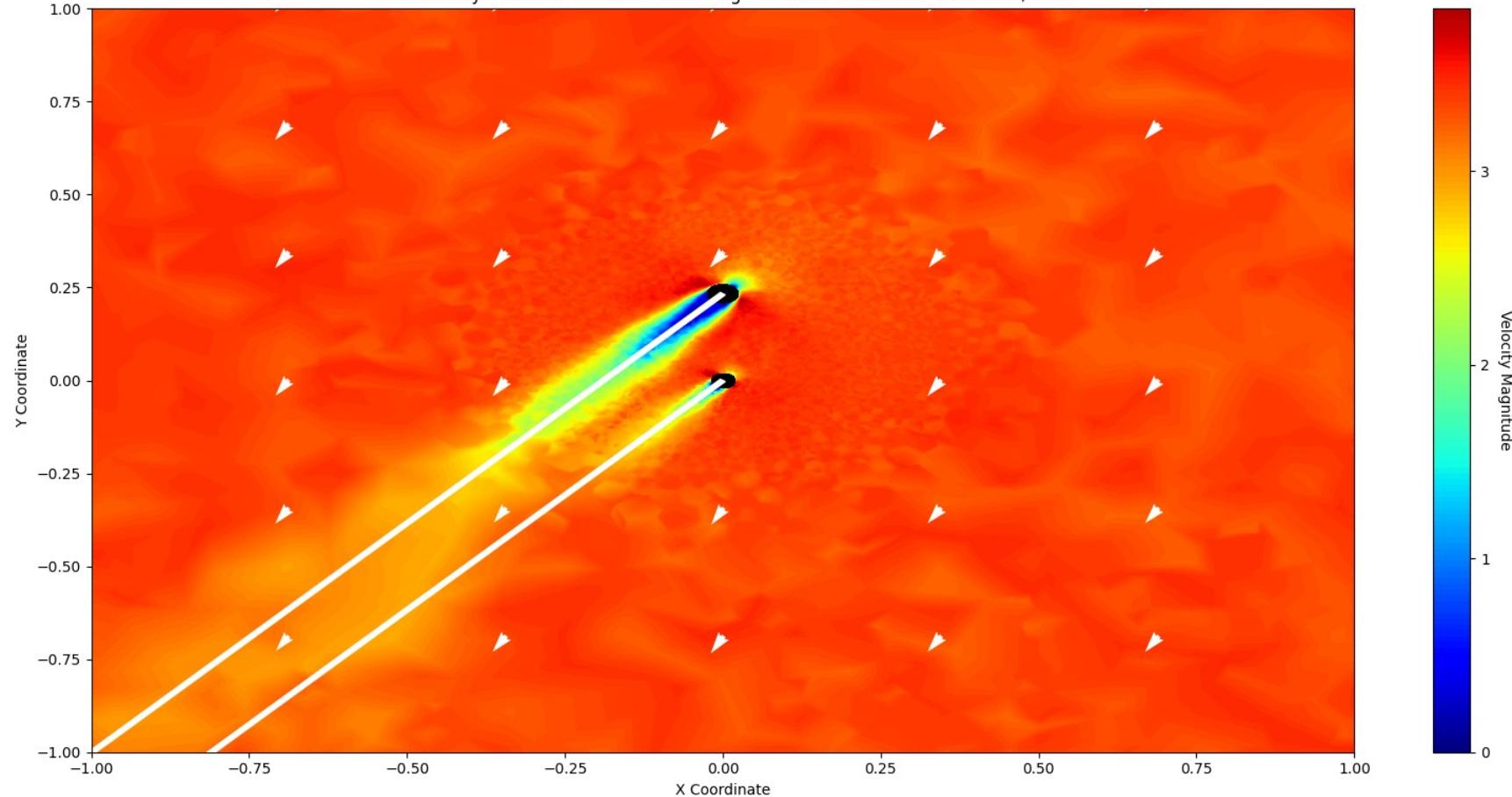
Total Velocity in the X-Y Plane for Wind Angle = 37 with a cut at Z = 0.17 +/- 0.02



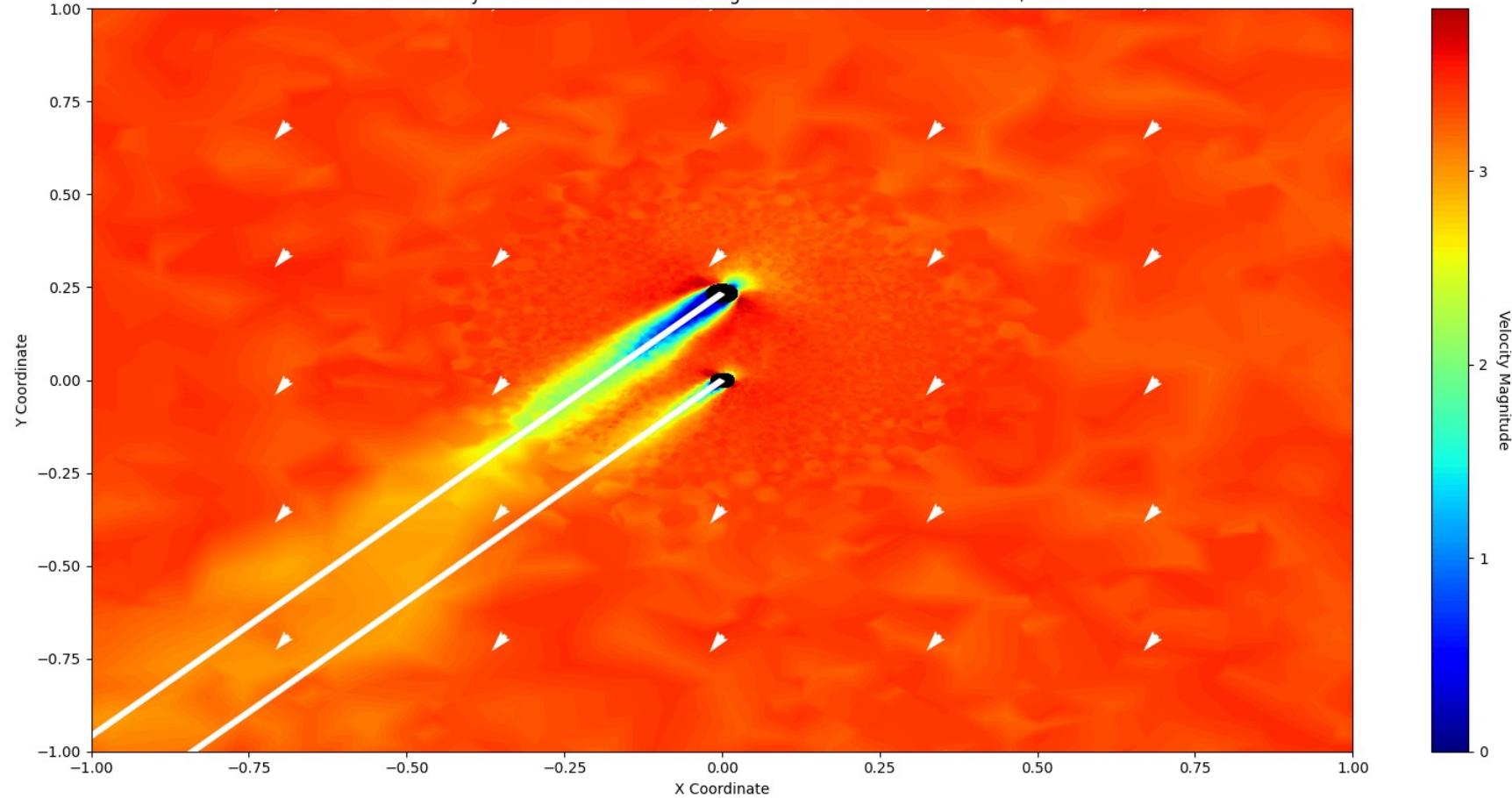
Total Velocity in the X-Y Plane for Wind Angle = 38 with a cut at Z = 0.17 +/- 0.02



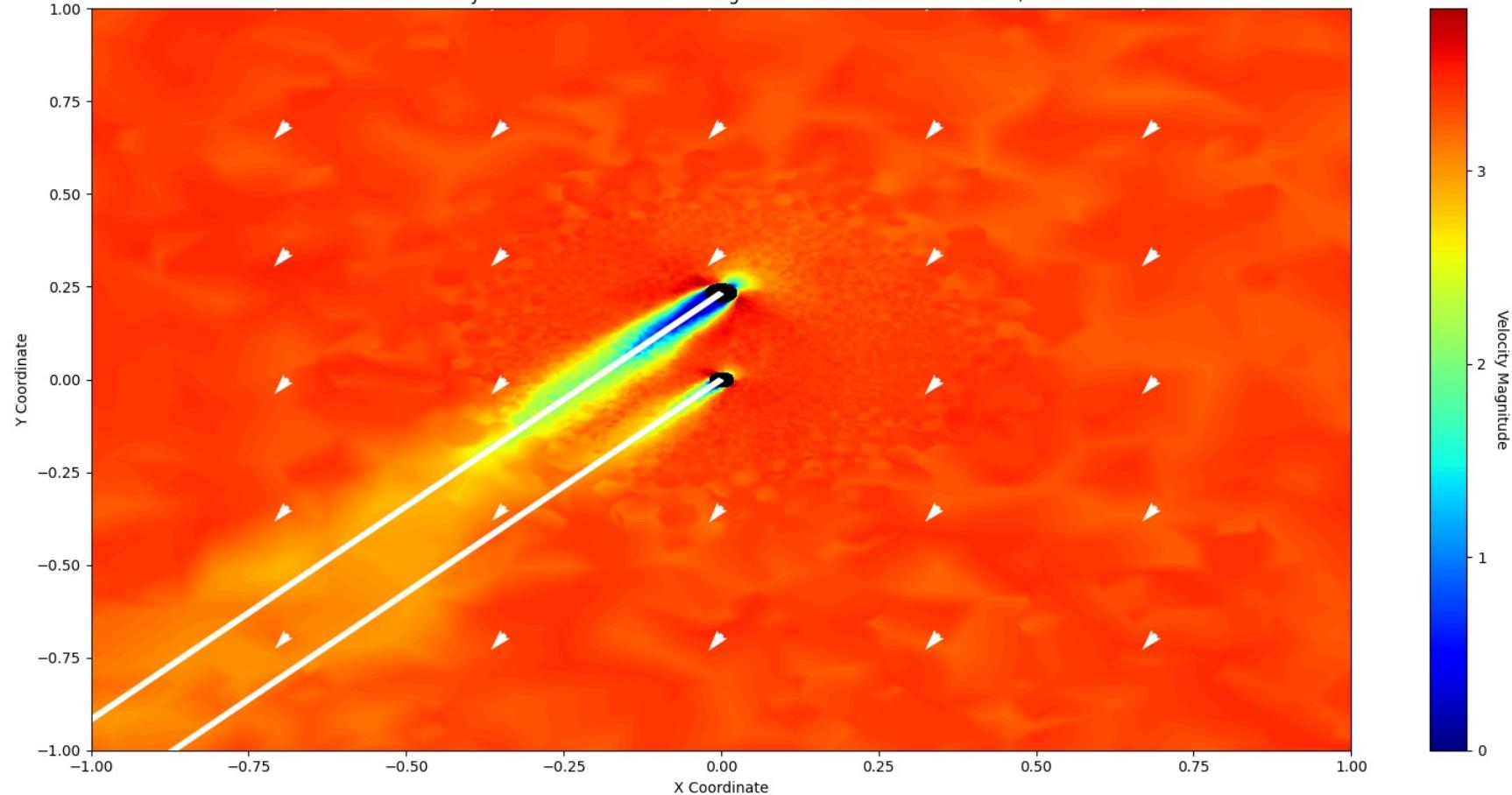
Total Velocity in the X-Y Plane for Wind Angle = 39 with a cut at Z = 0.17 +/- 0.02



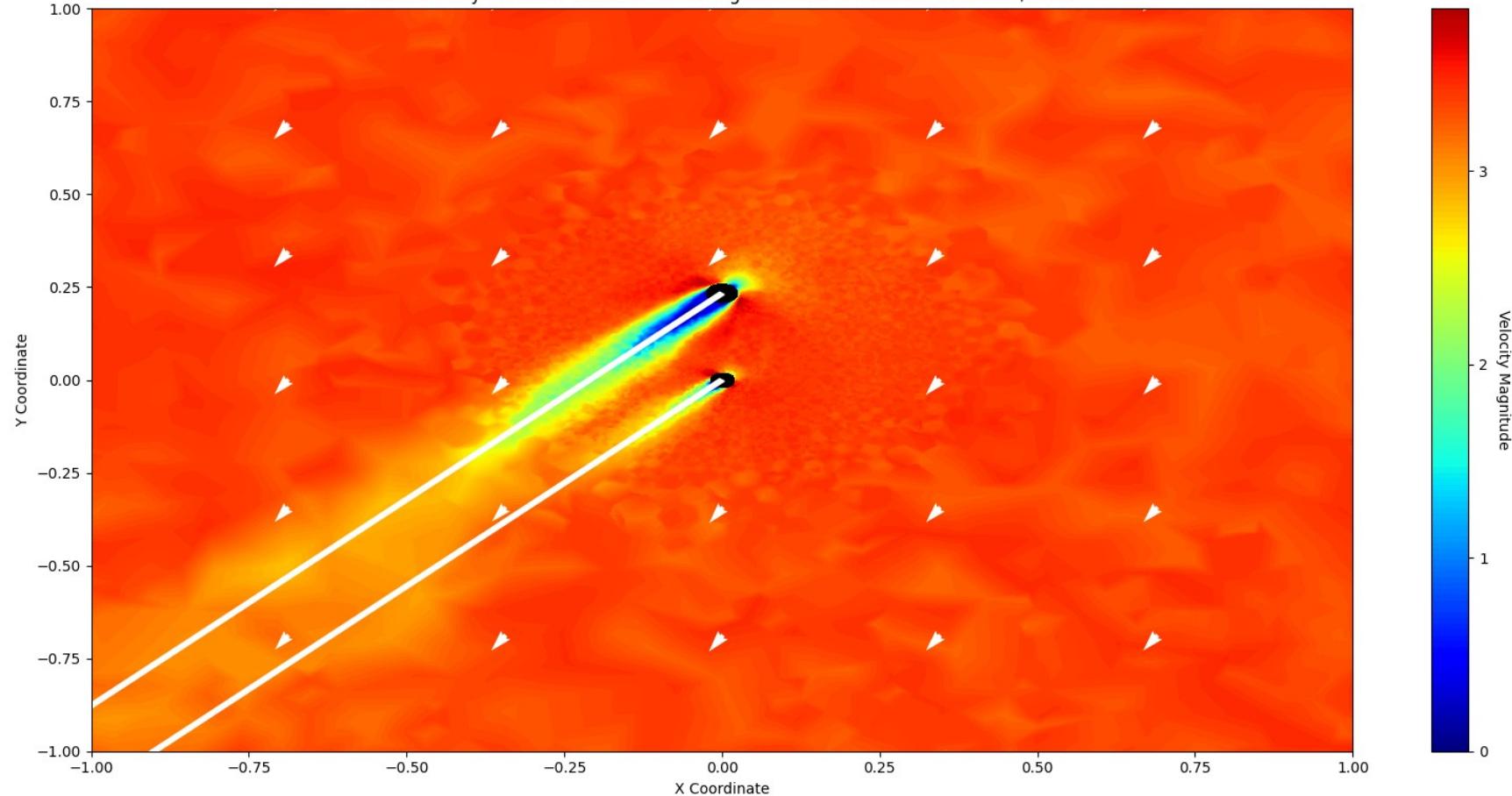
Total Velocity in the X-Y Plane for Wind Angle = 40 with a cut at Z = 0.17 +/- 0.02



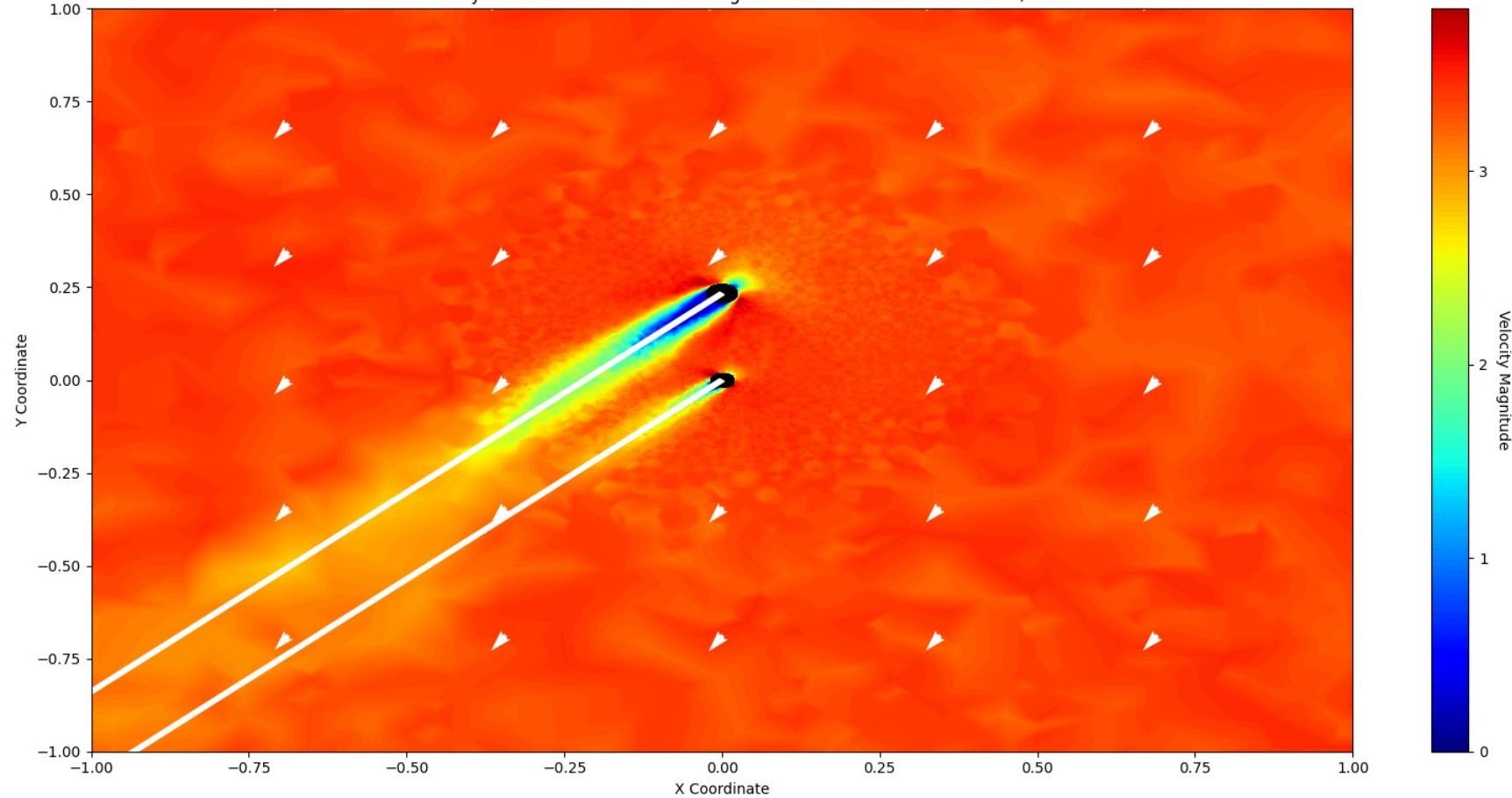
Total Velocity in the X-Y Plane for Wind Angle = 41 with a cut at Z = 0.17 +/- 0.02



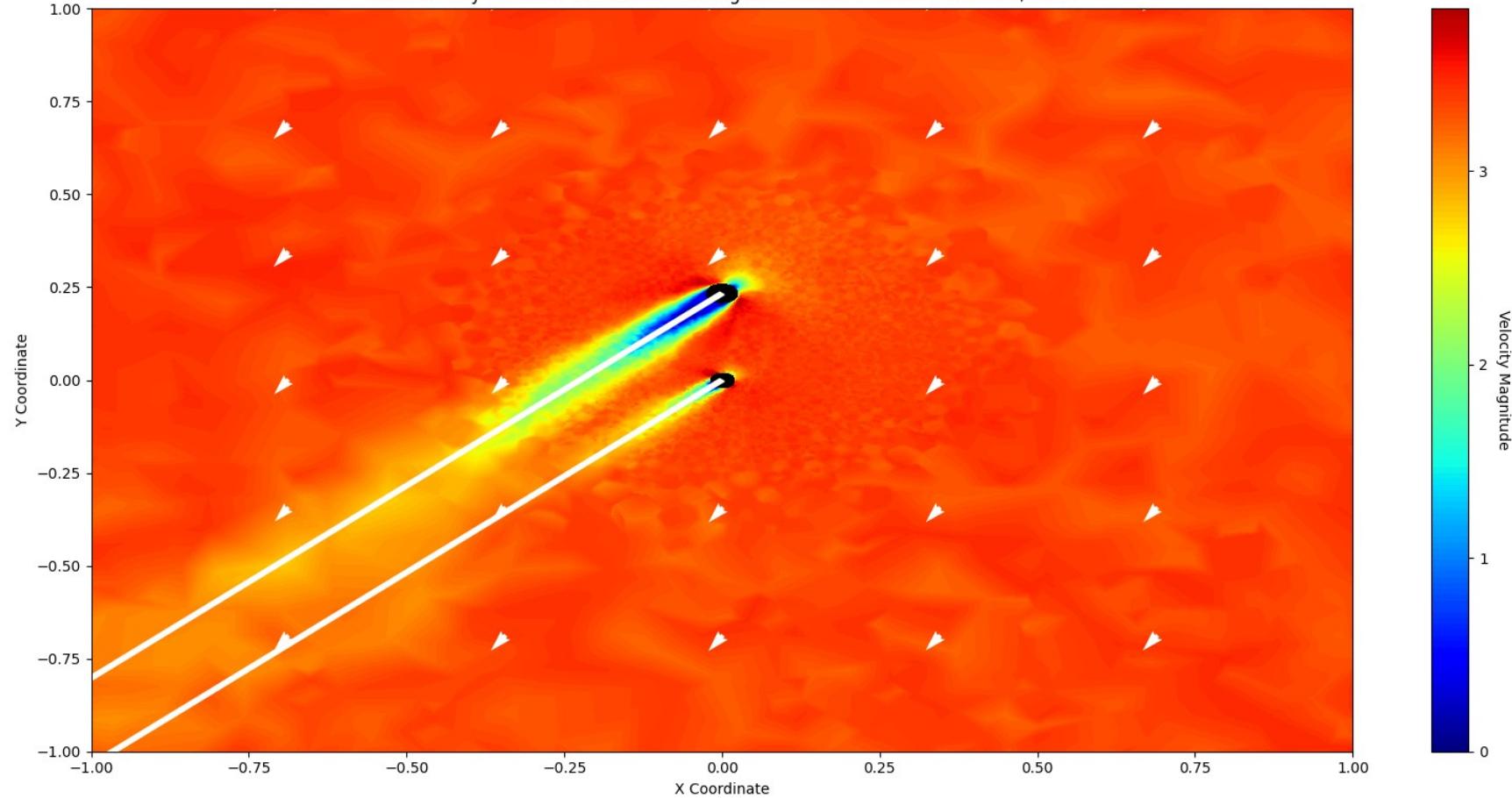
Total Velocity in the X-Y Plane for Wind Angle = 42 with a cut at Z = 0.17 +/- 0.02



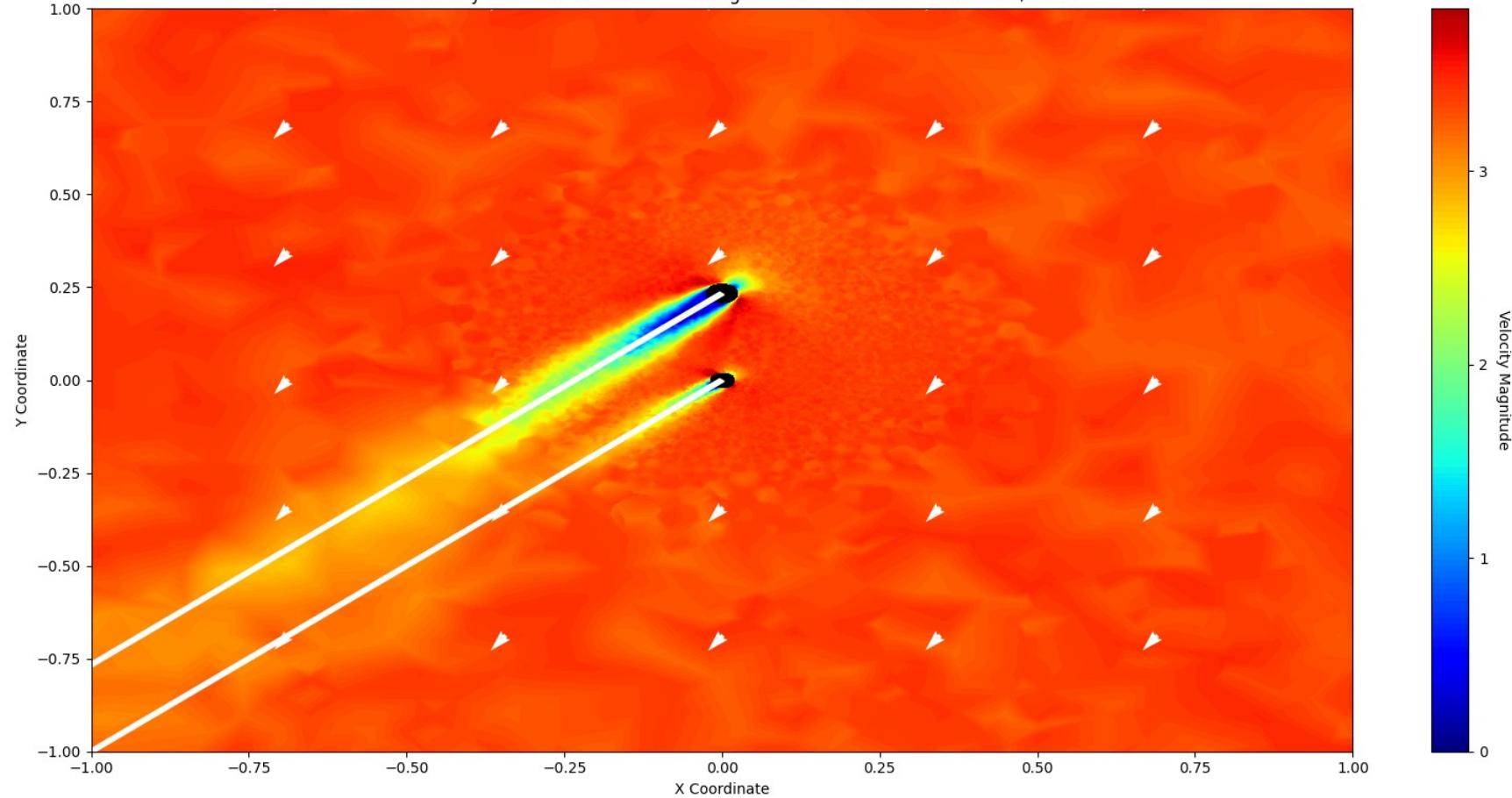
Total Velocity in the X-Y Plane for Wind Angle = 43 with a cut at Z = 0.17 +/- 0.02



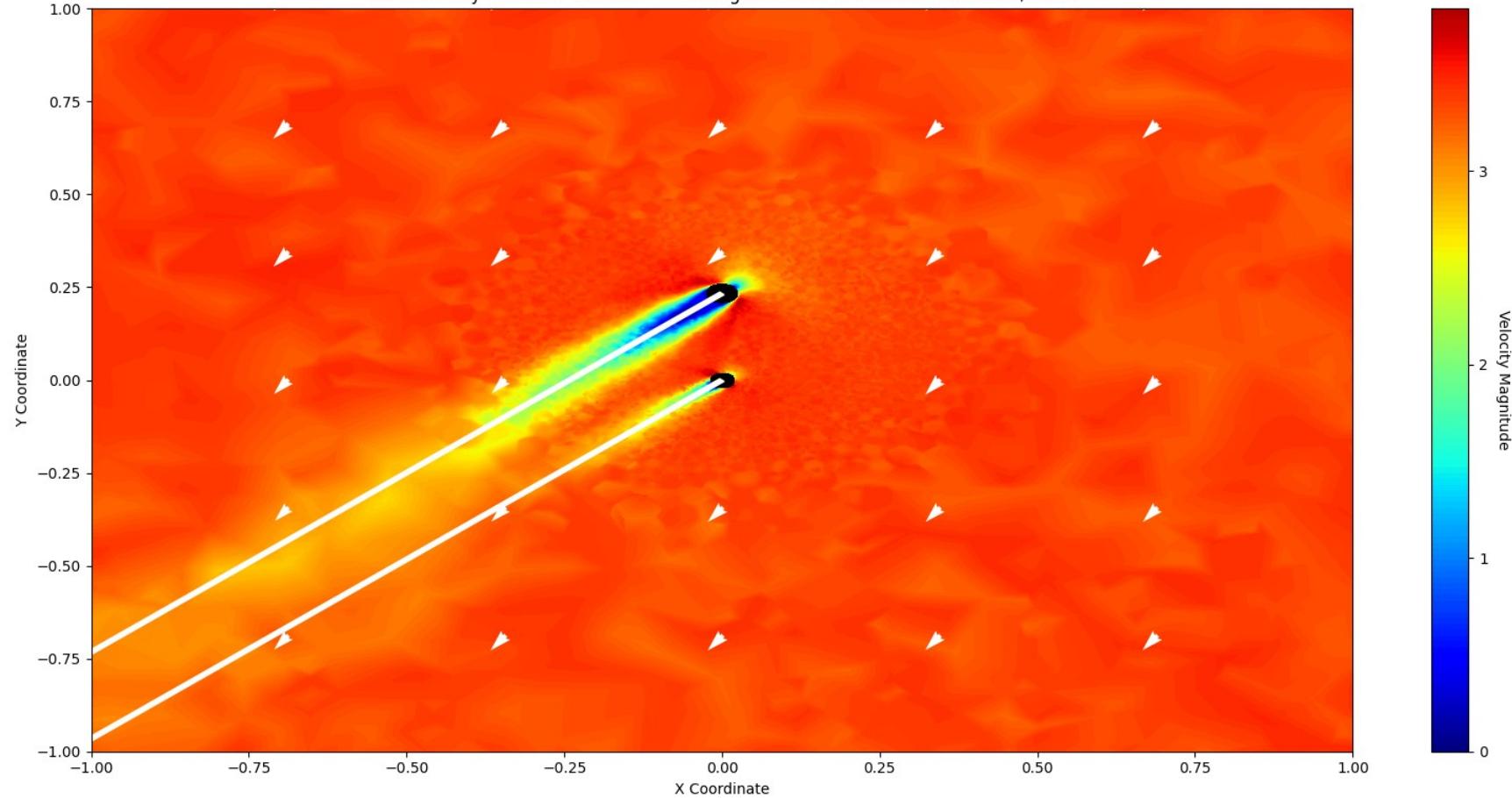
Total Velocity in the X-Y Plane for Wind Angle = 44 with a cut at Z = 0.17 +/- 0.02



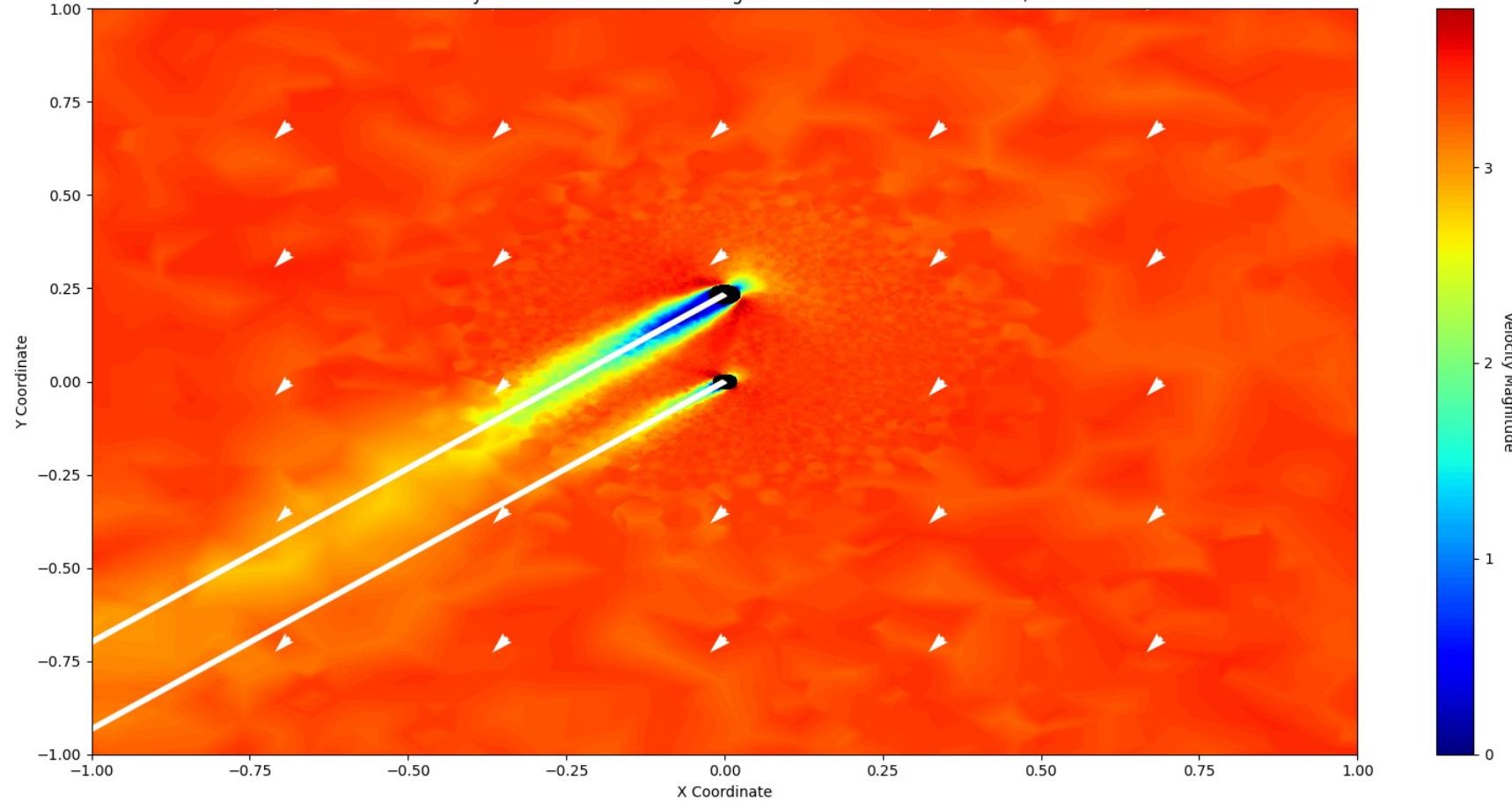
Total Velocity in the X-Y Plane for Wind Angle = 45 with a cut at Z = 0.17 +/- 0.02



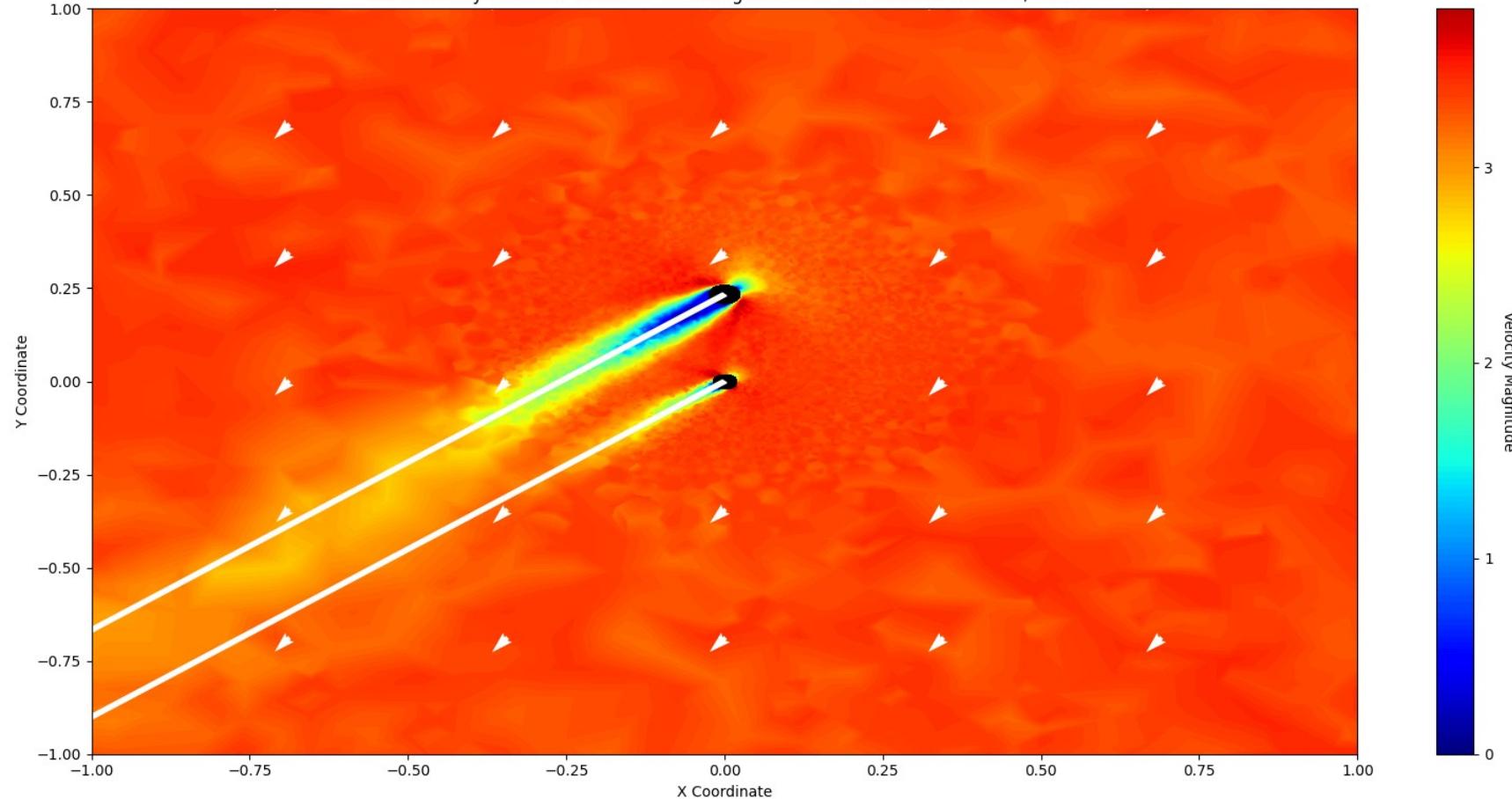
Total Velocity in the X-Y Plane for Wind Angle = 46 with a cut at Z = 0.17 +/- 0.02



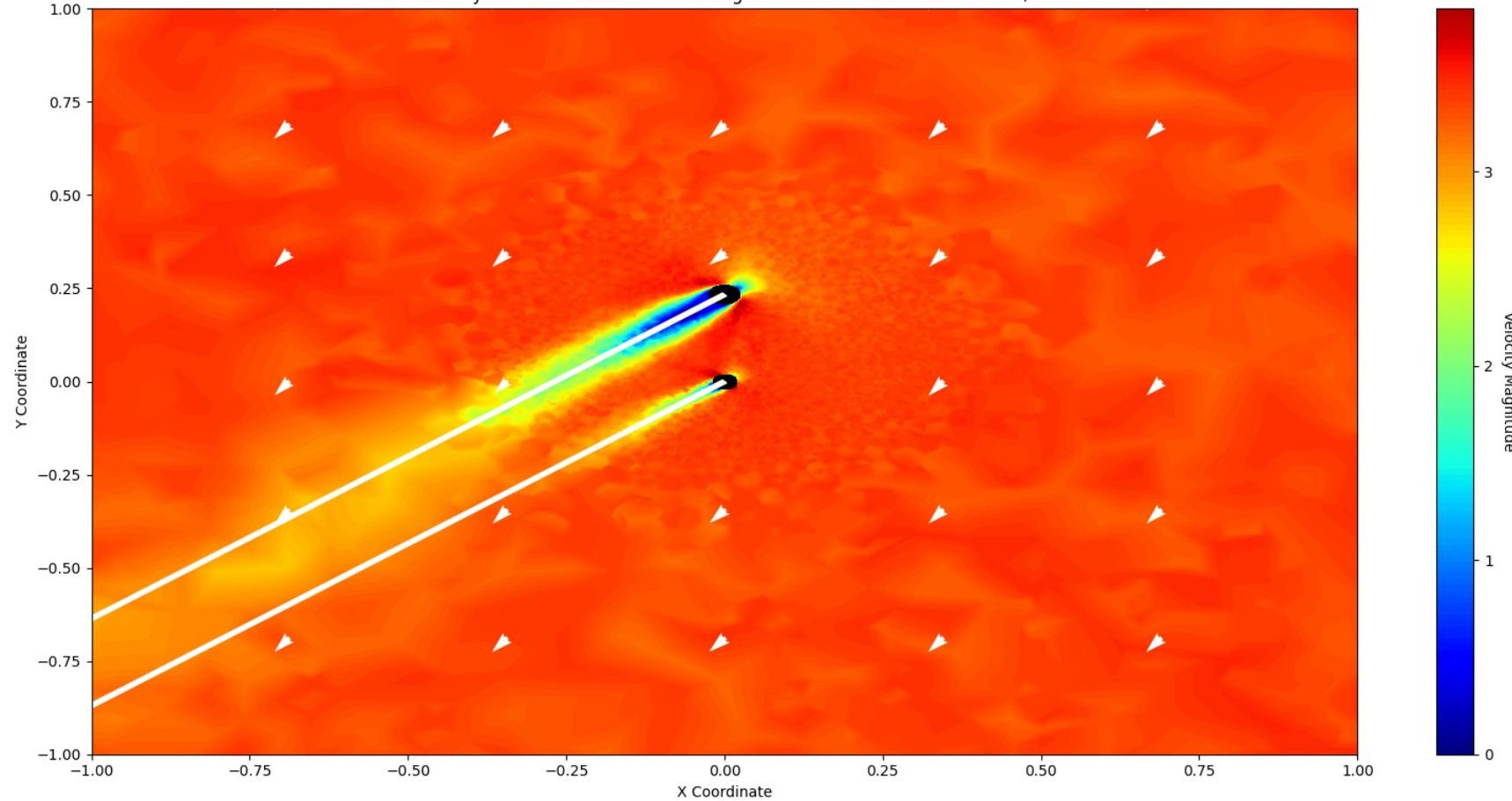
Total Velocity in the X-Y Plane for Wind Angle = 47 with a cut at Z = 0.17 +/- 0.02



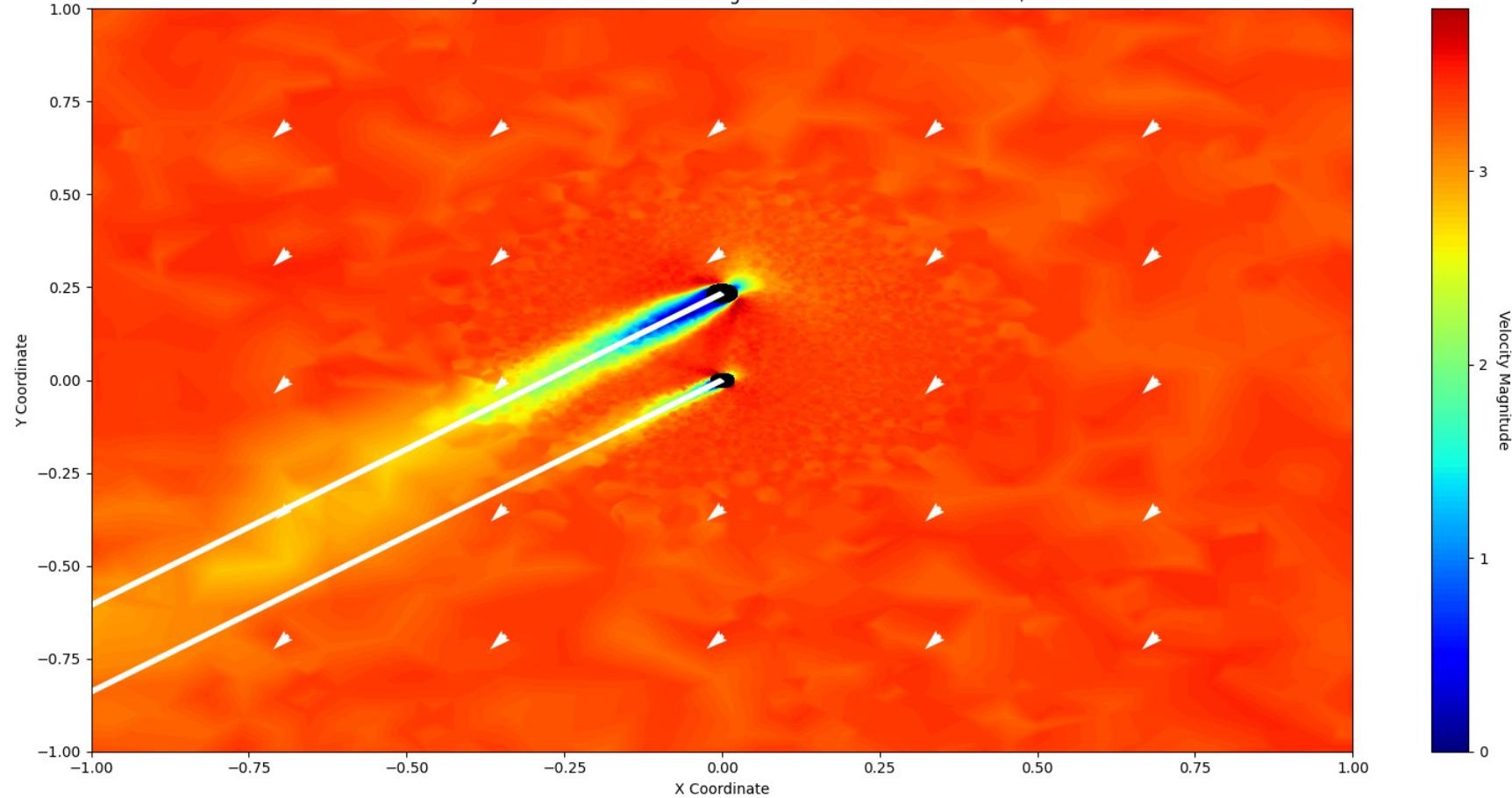
Total Velocity in the X-Y Plane for Wind Angle = 48 with a cut at Z = 0.17 +/- 0.02



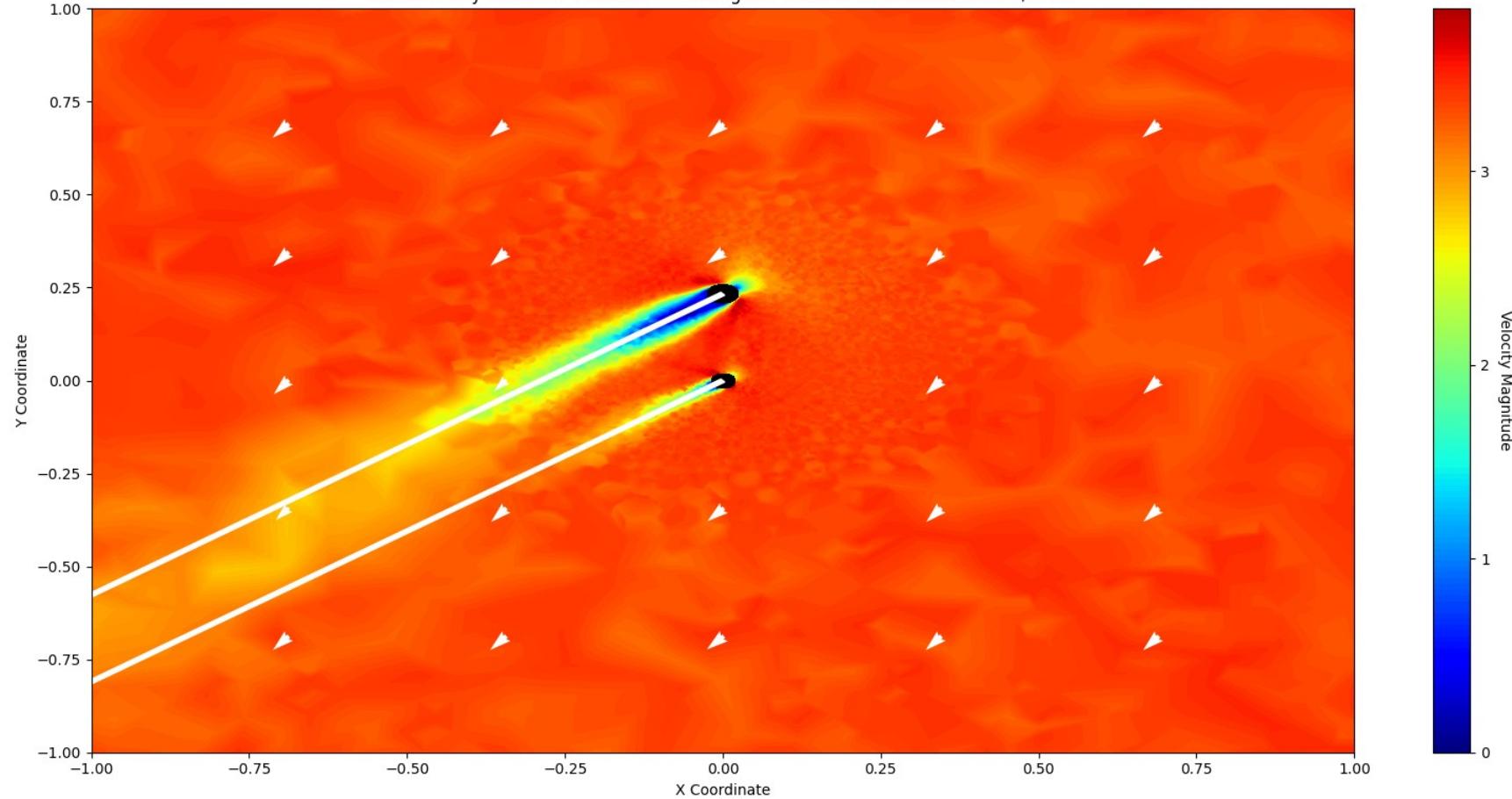
Total Velocity in the X-Y Plane for Wind Angle = 49 with a cut at Z = 0.17 +/- 0.02



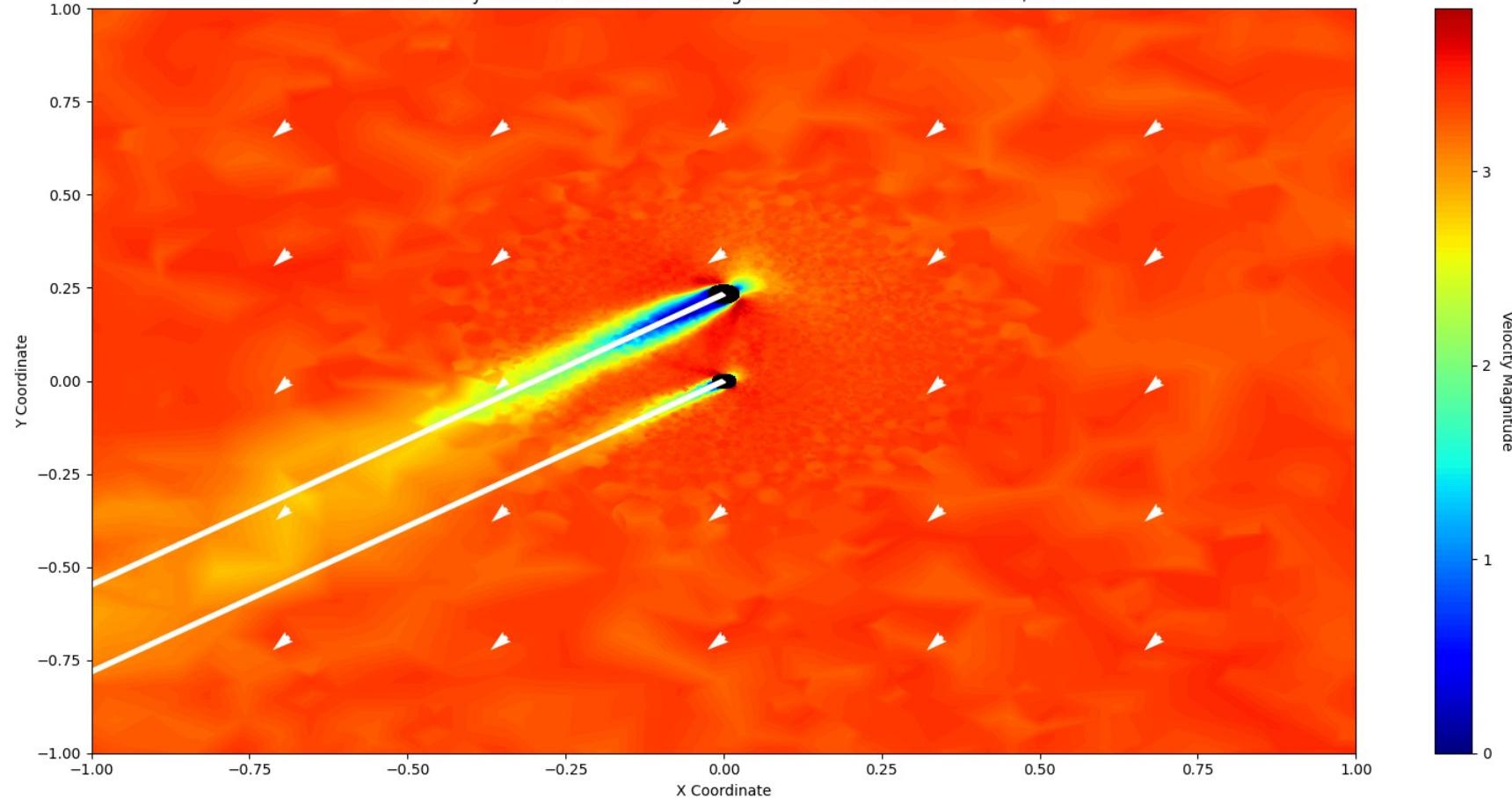
Total Velocity in the X-Y Plane for Wind Angle = 50 with a cut at Z = 0.17 +/- 0.02



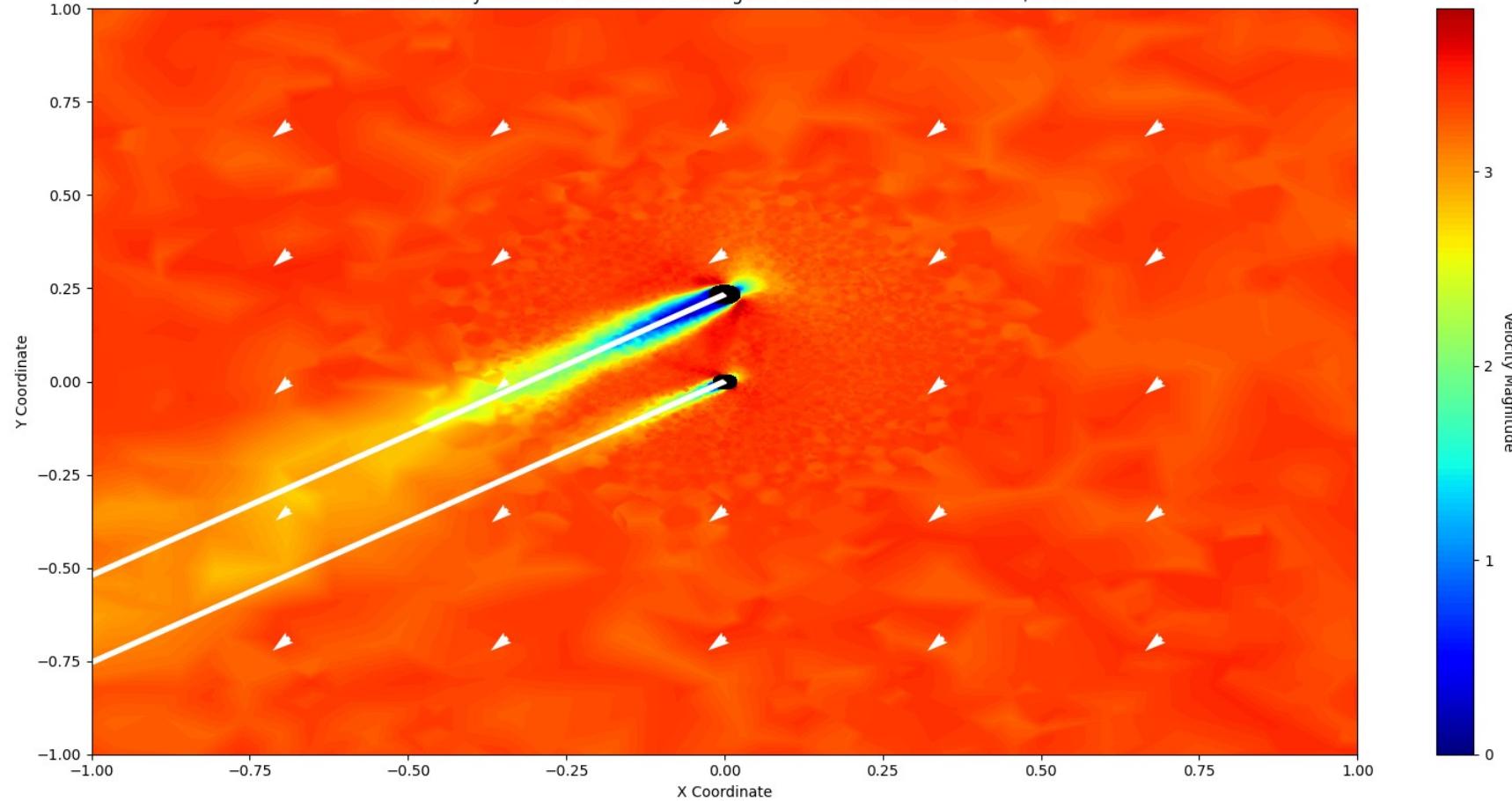
Total Velocity in the X-Y Plane for Wind Angle = 51 with a cut at Z = 0.17 +/- 0.02



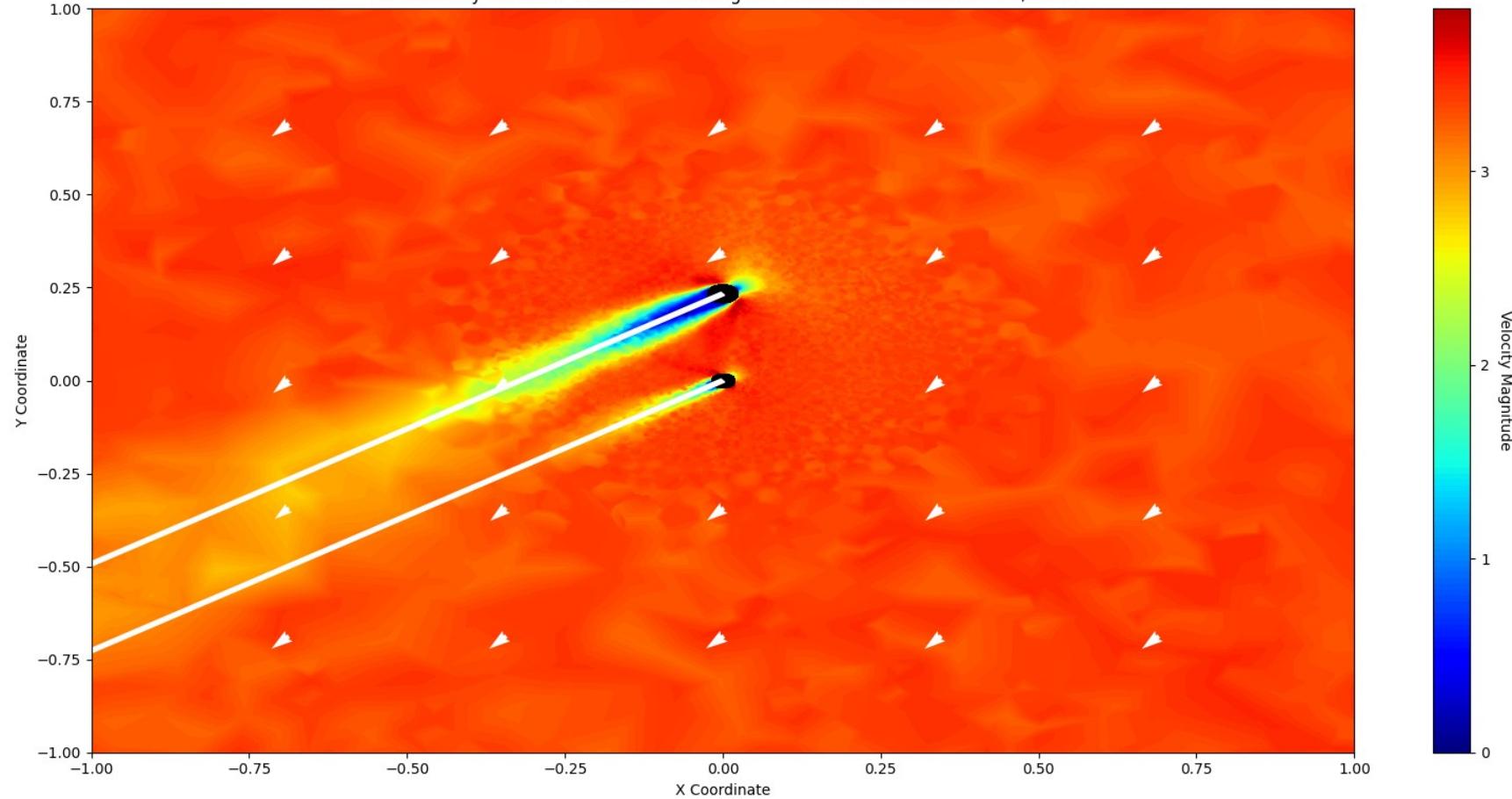
Total Velocity in the X-Y Plane for Wind Angle = 52 with a cut at Z = 0.17 +/- 0.02



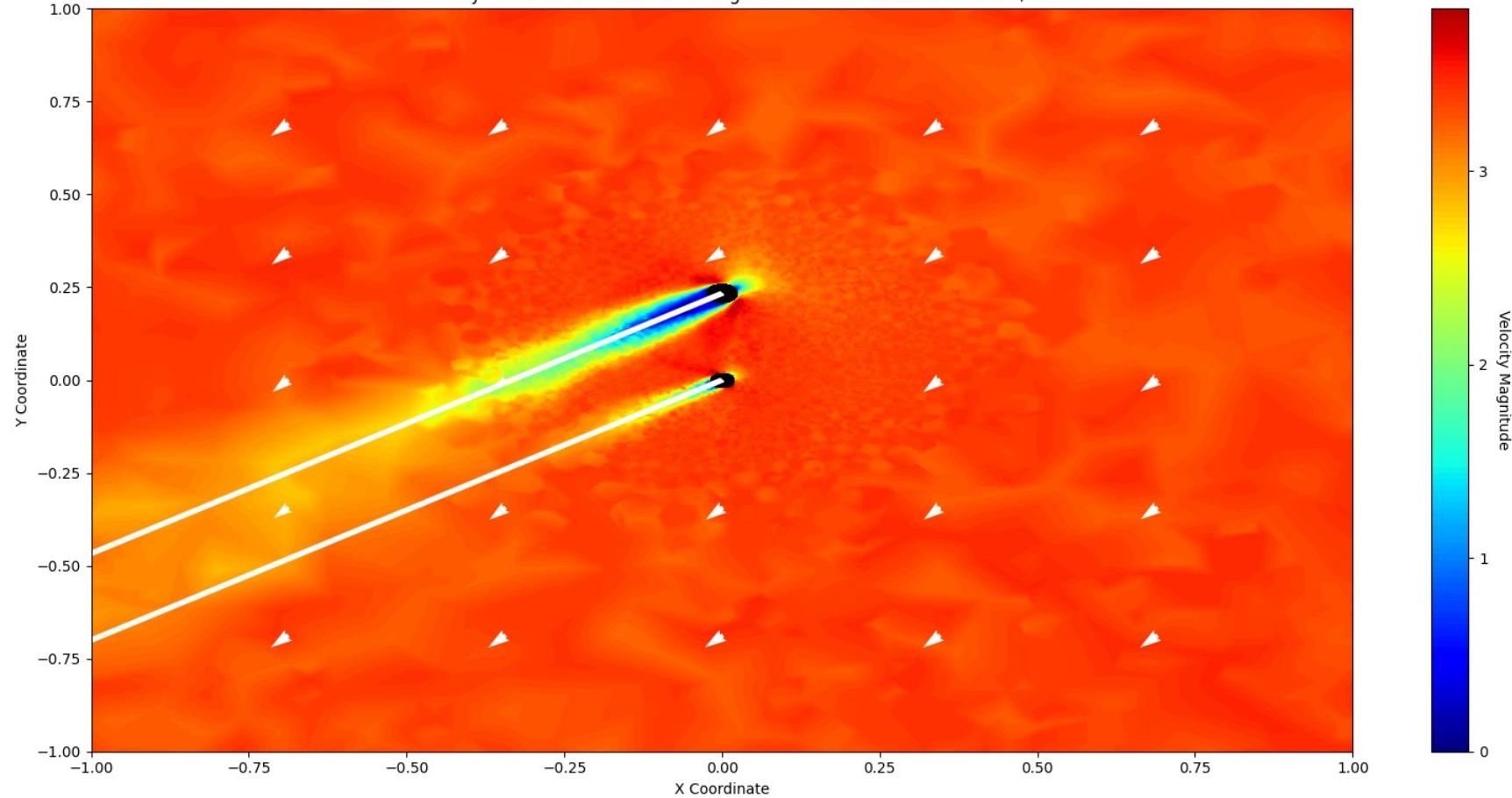
Total Velocity in the X-Y Plane for Wind Angle = 53 with a cut at Z = 0.17 +/- 0.02



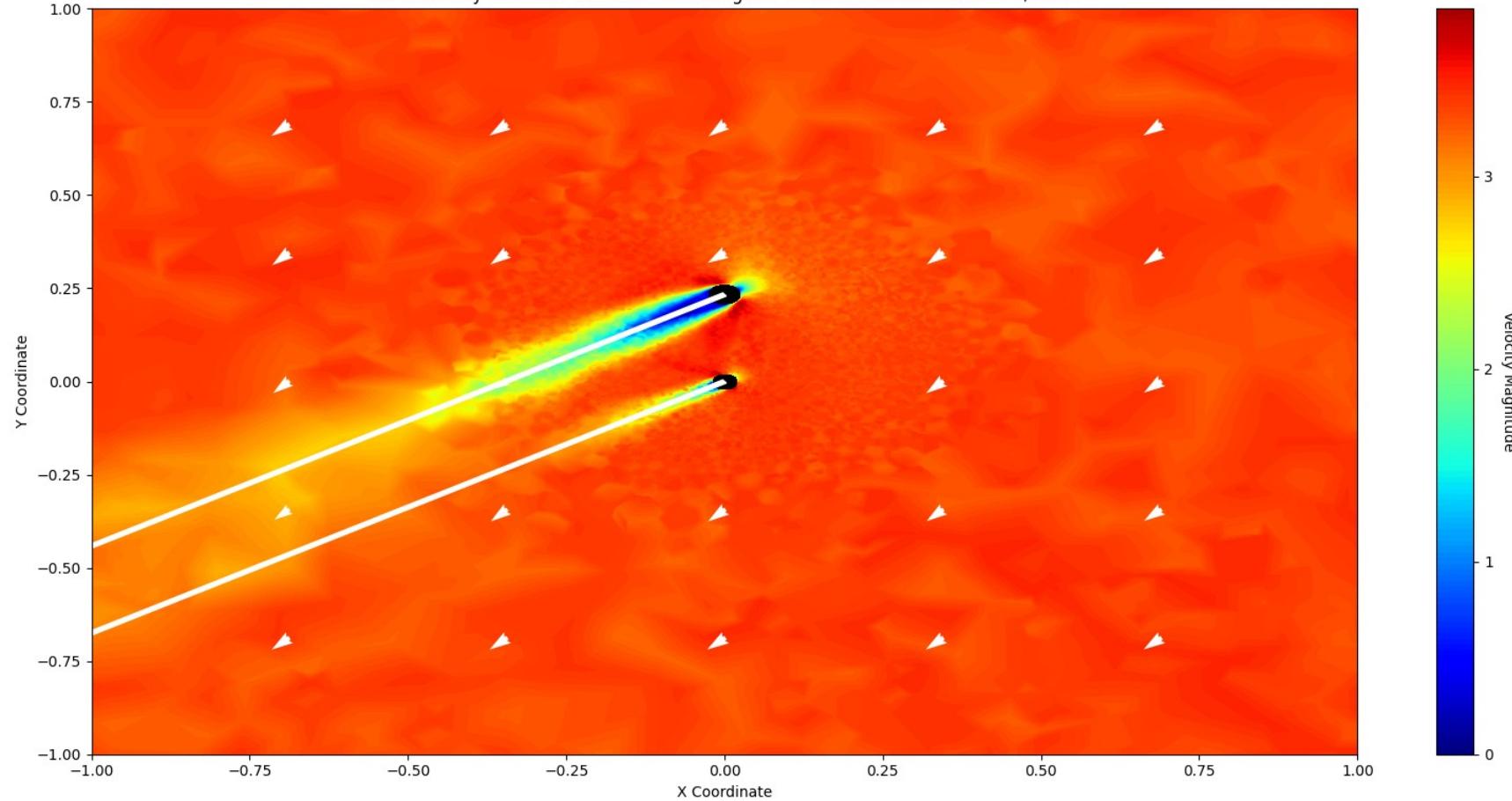
Total Velocity in the X-Y Plane for Wind Angle = 54 with a cut at Z = 0.17 +/- 0.02



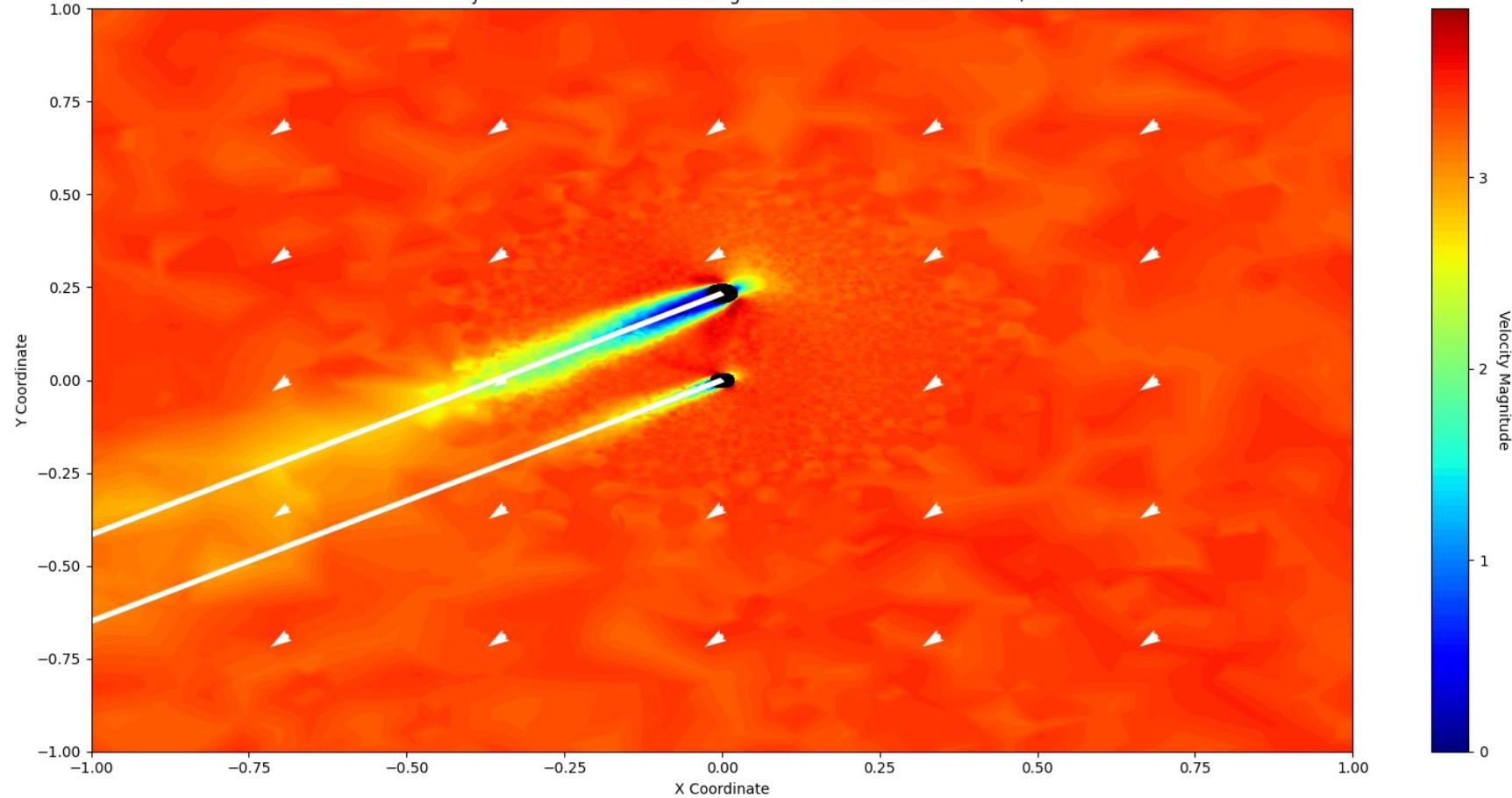
Total Velocity in the X-Y Plane for Wind Angle = 55 with a cut at Z = 0.17 +/- 0.02



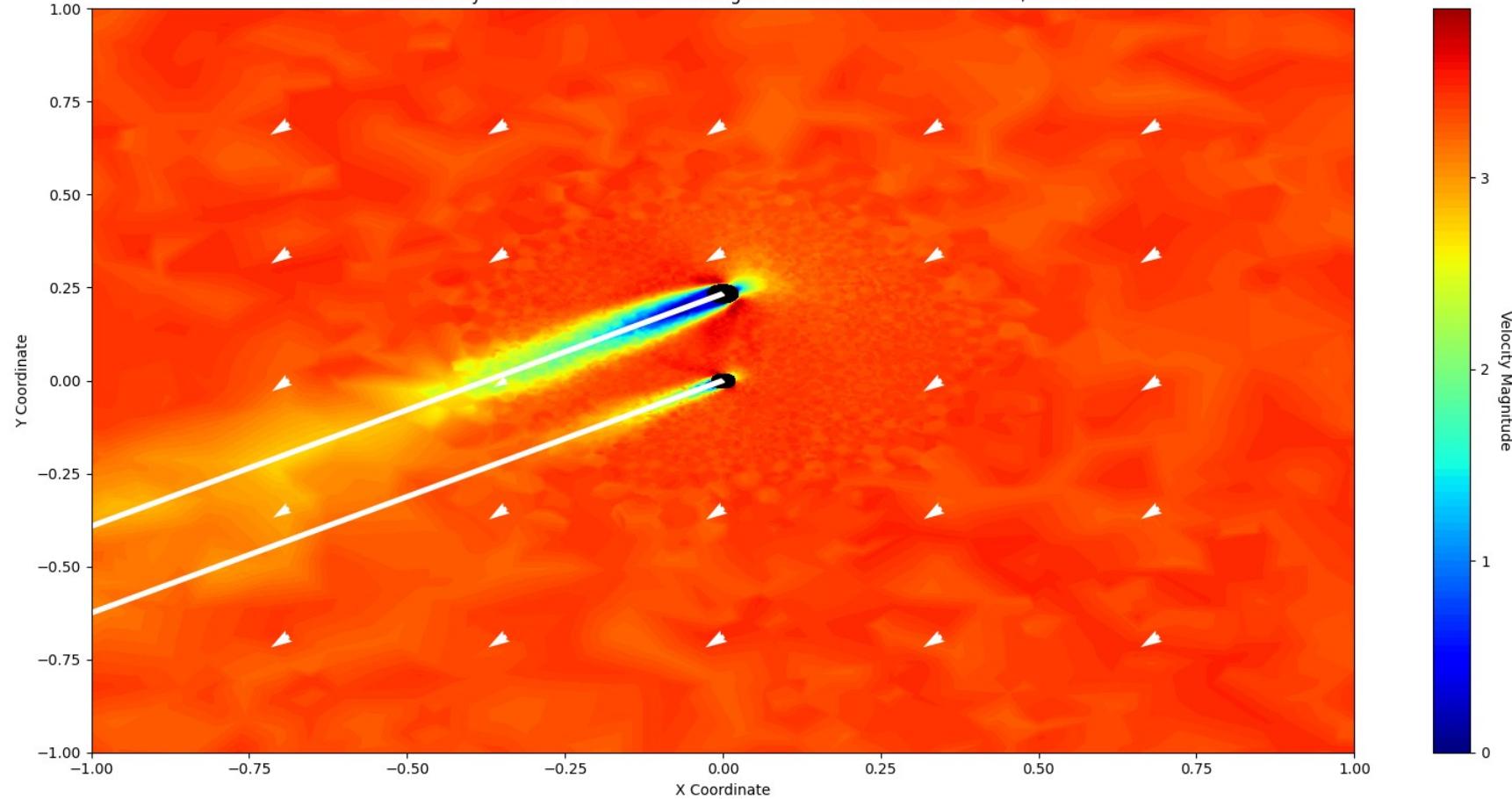
Total Velocity in the X-Y Plane for Wind Angle = 56 with a cut at Z = 0.17 +/- 0.02



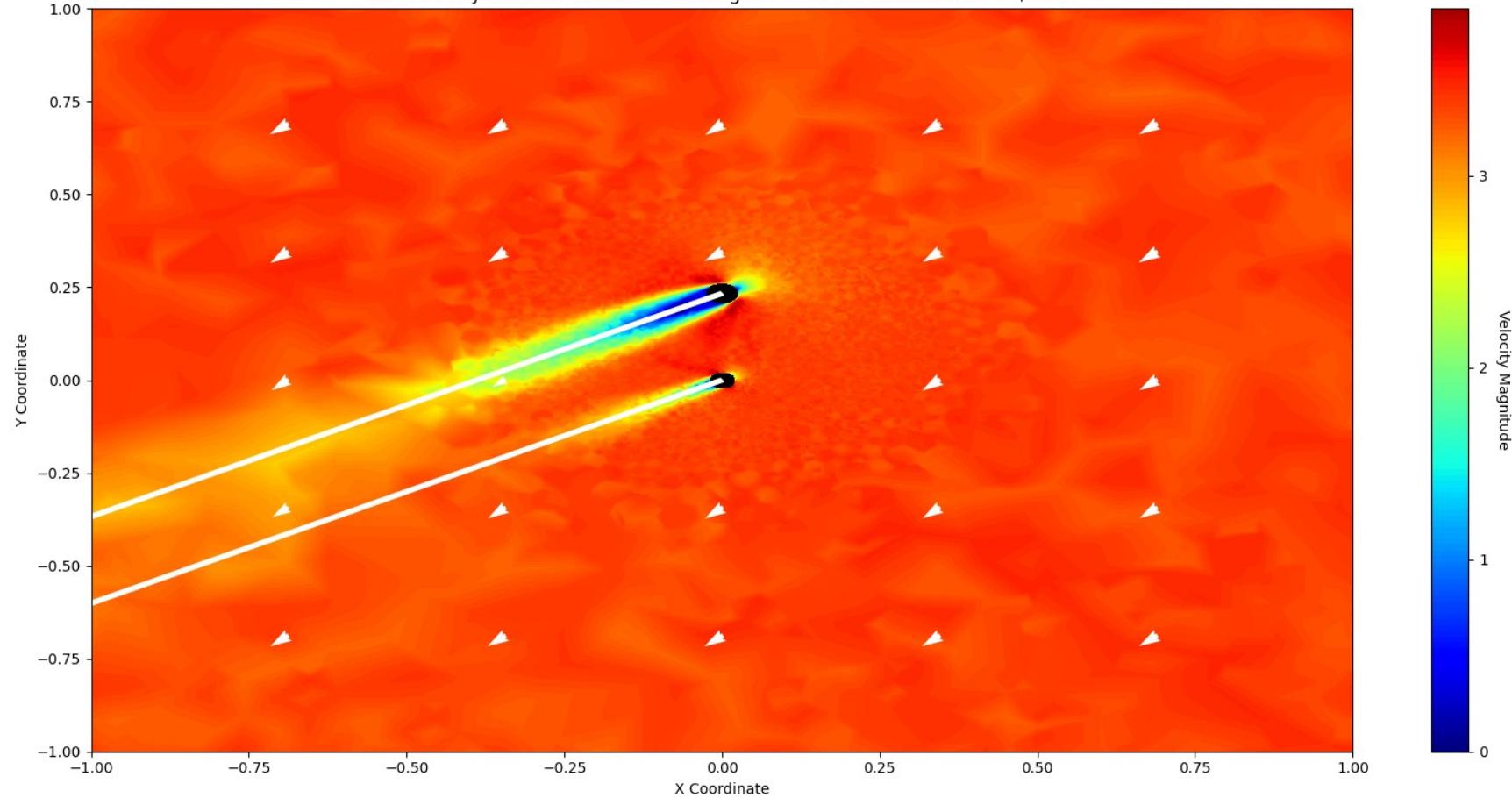
Total Velocity in the X-Y Plane for Wind Angle = 57 with a cut at Z = 0.17 +/- 0.02



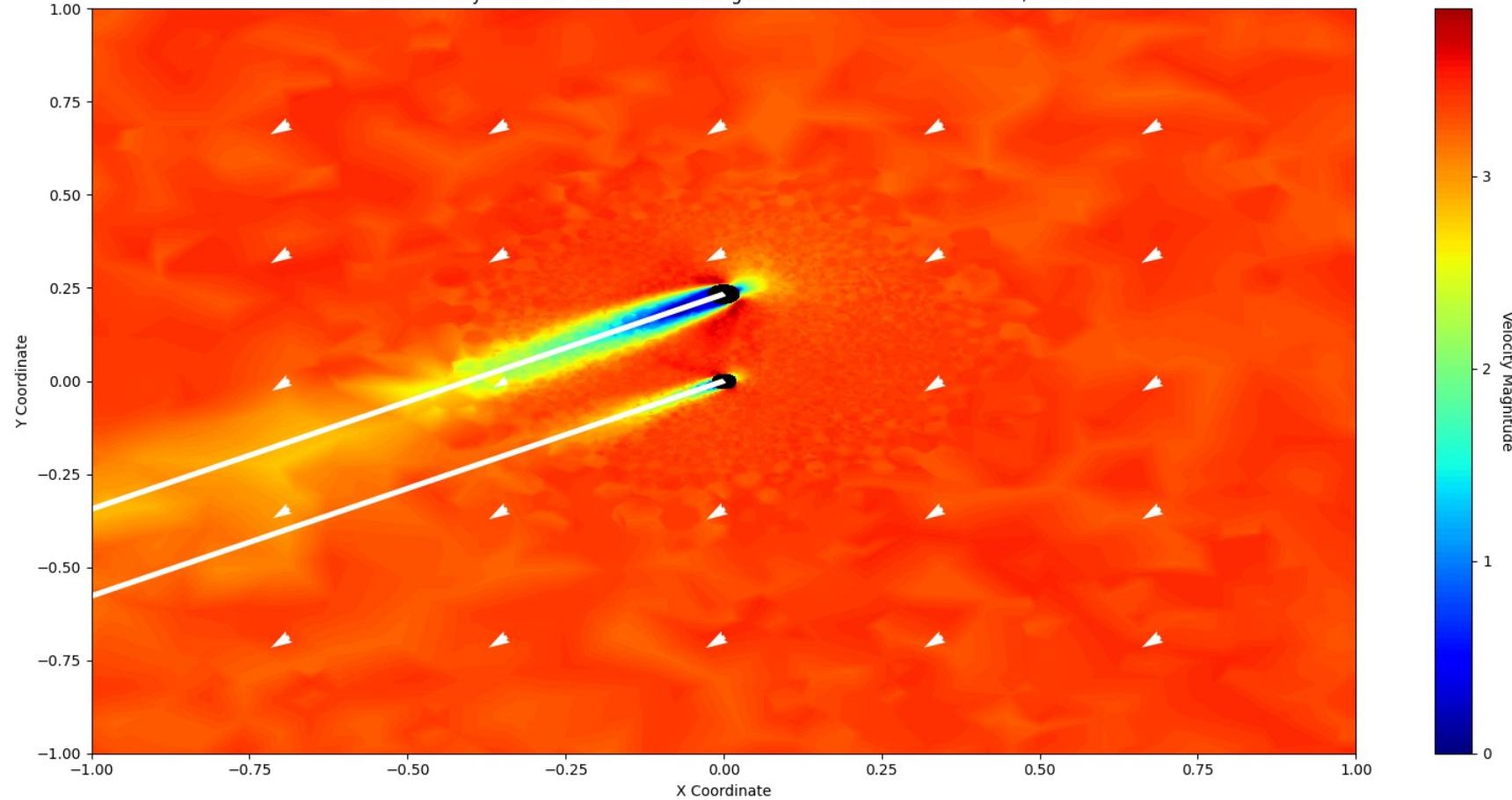
Total Velocity in the X-Y Plane for Wind Angle = 58 with a cut at Z = 0.17 +/- 0.02



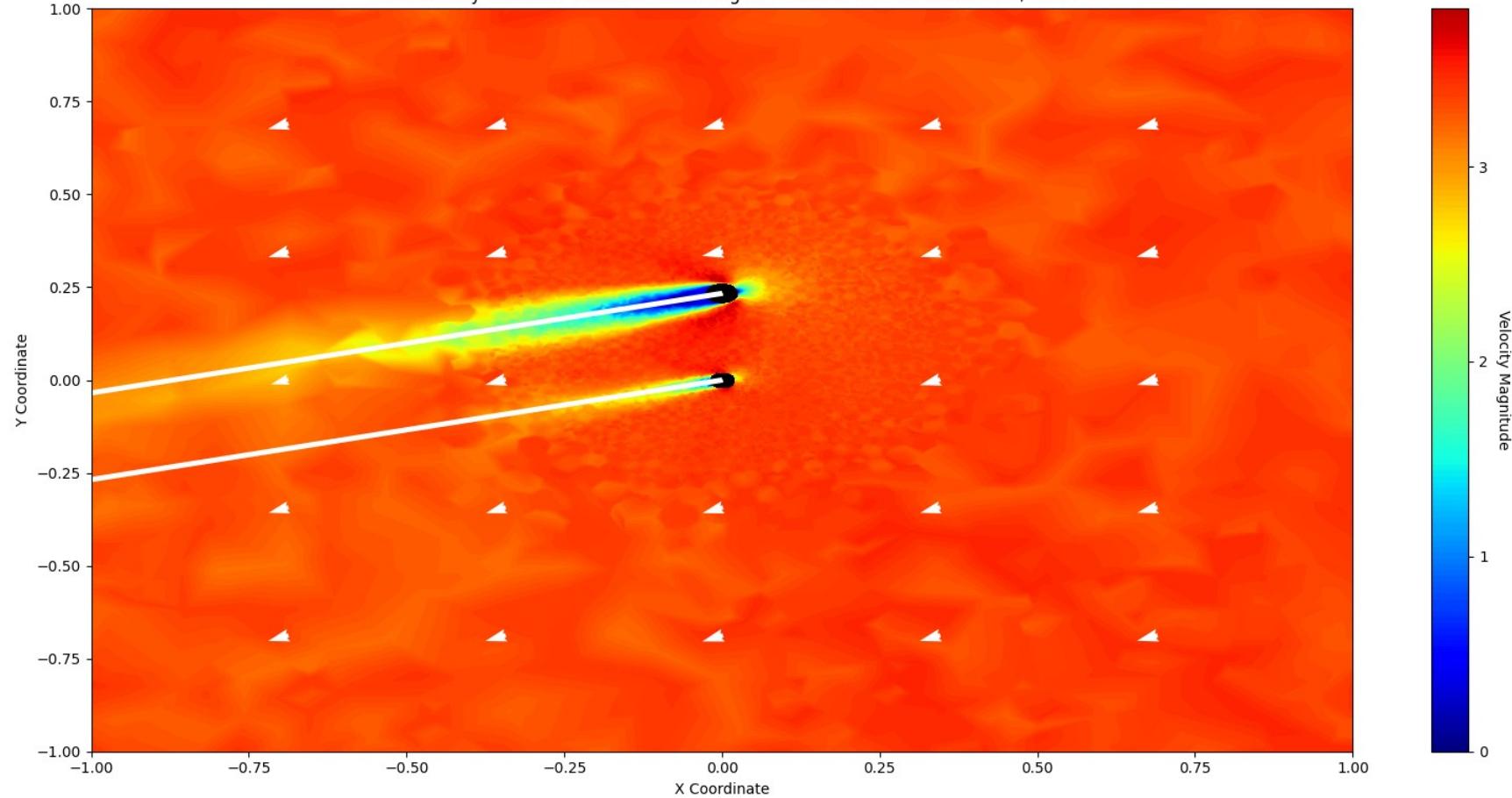
Total Velocity in the X-Y Plane for Wind Angle = 59 with a cut at Z = 0.17 +/- 0.02



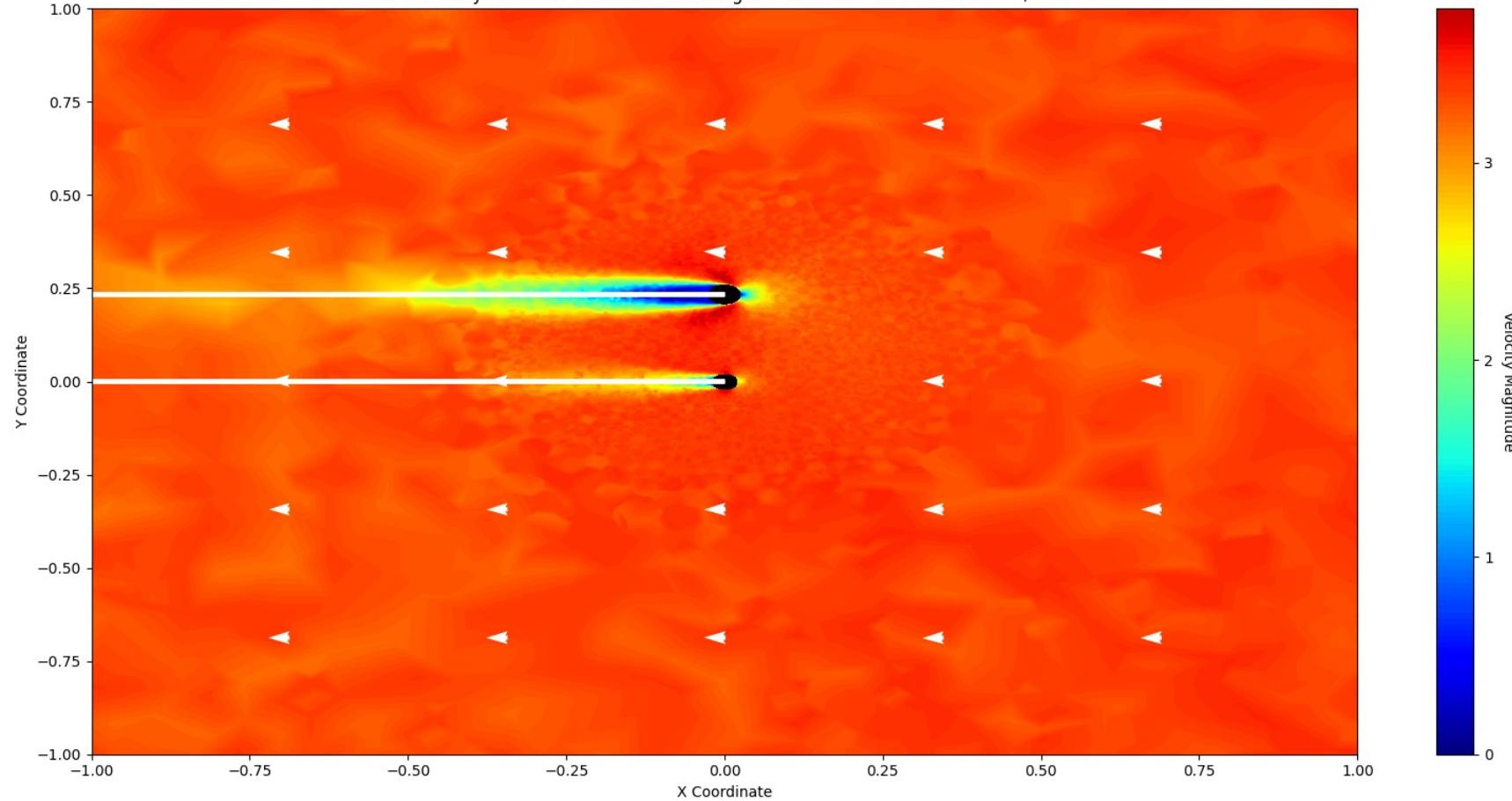
Total Velocity in the X-Y Plane for Wind Angle = 60 with a cut at Z = 0.17 +/- 0.02



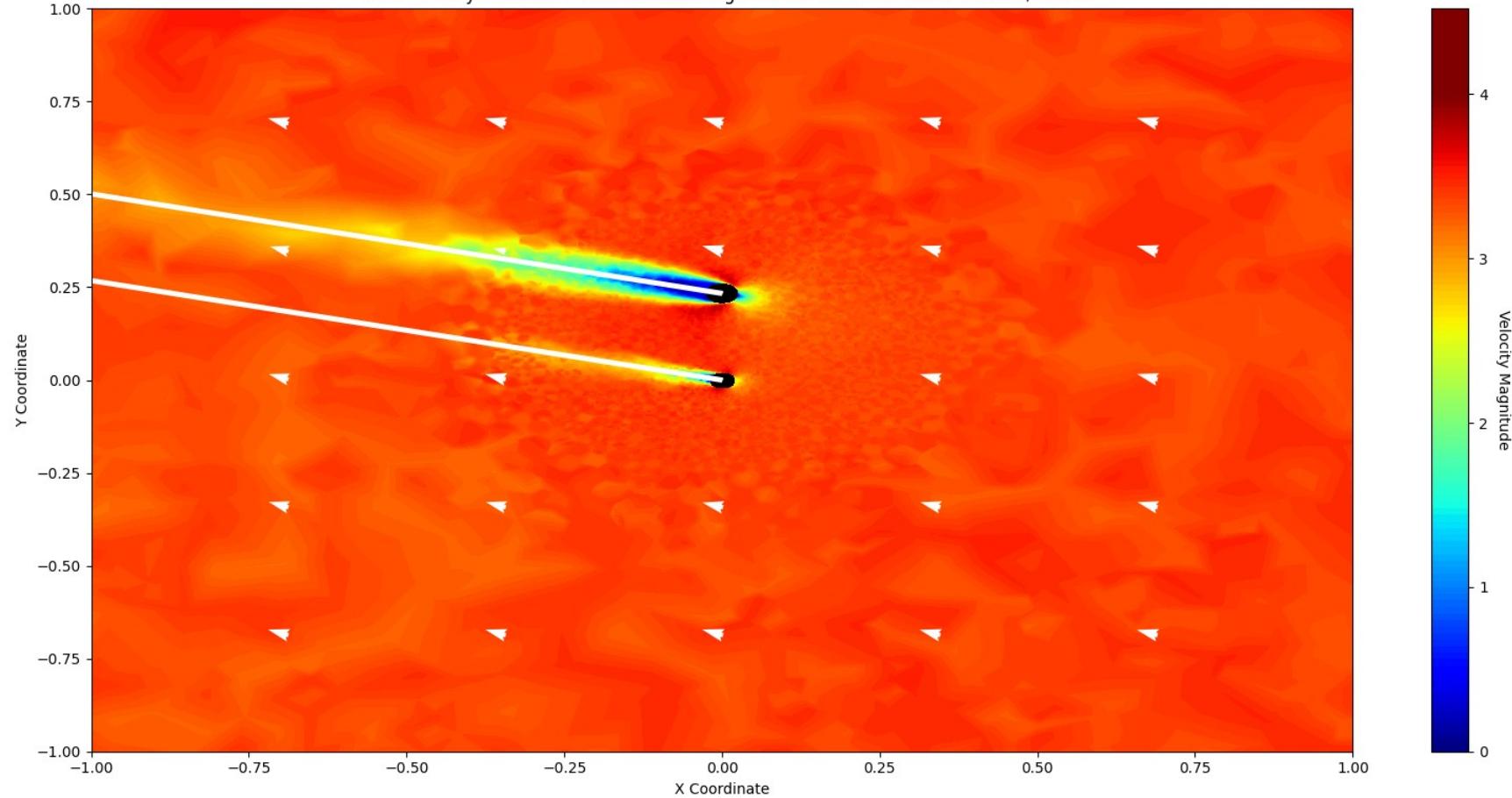
Total Velocity in the X-Y Plane for Wind Angle = 75 with a cut at Z = 0.17 +/- 0.02



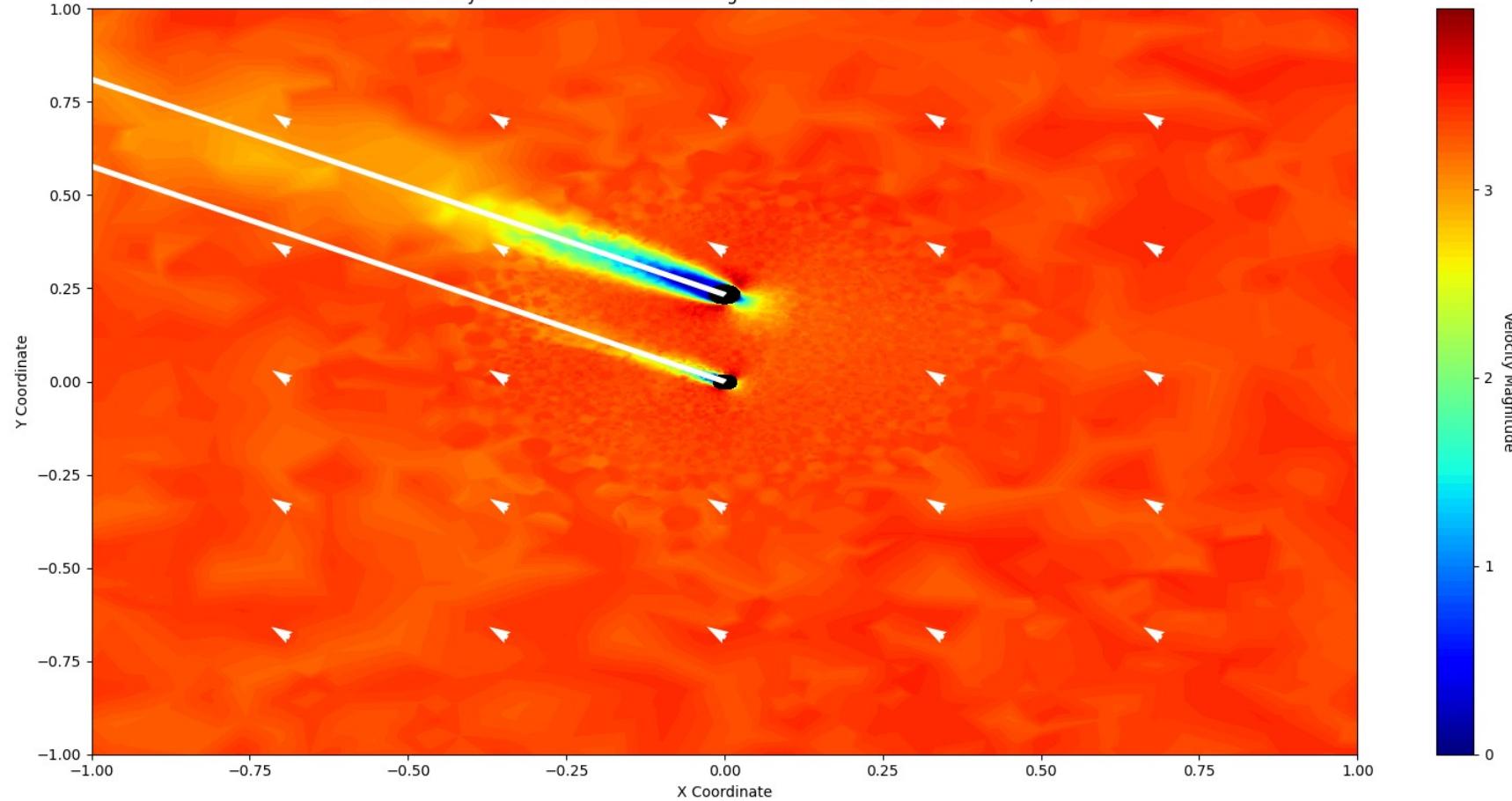
Total Velocity in the X-Y Plane for Wind Angle = 90 with a cut at Z = 0.17 +/- 0.02



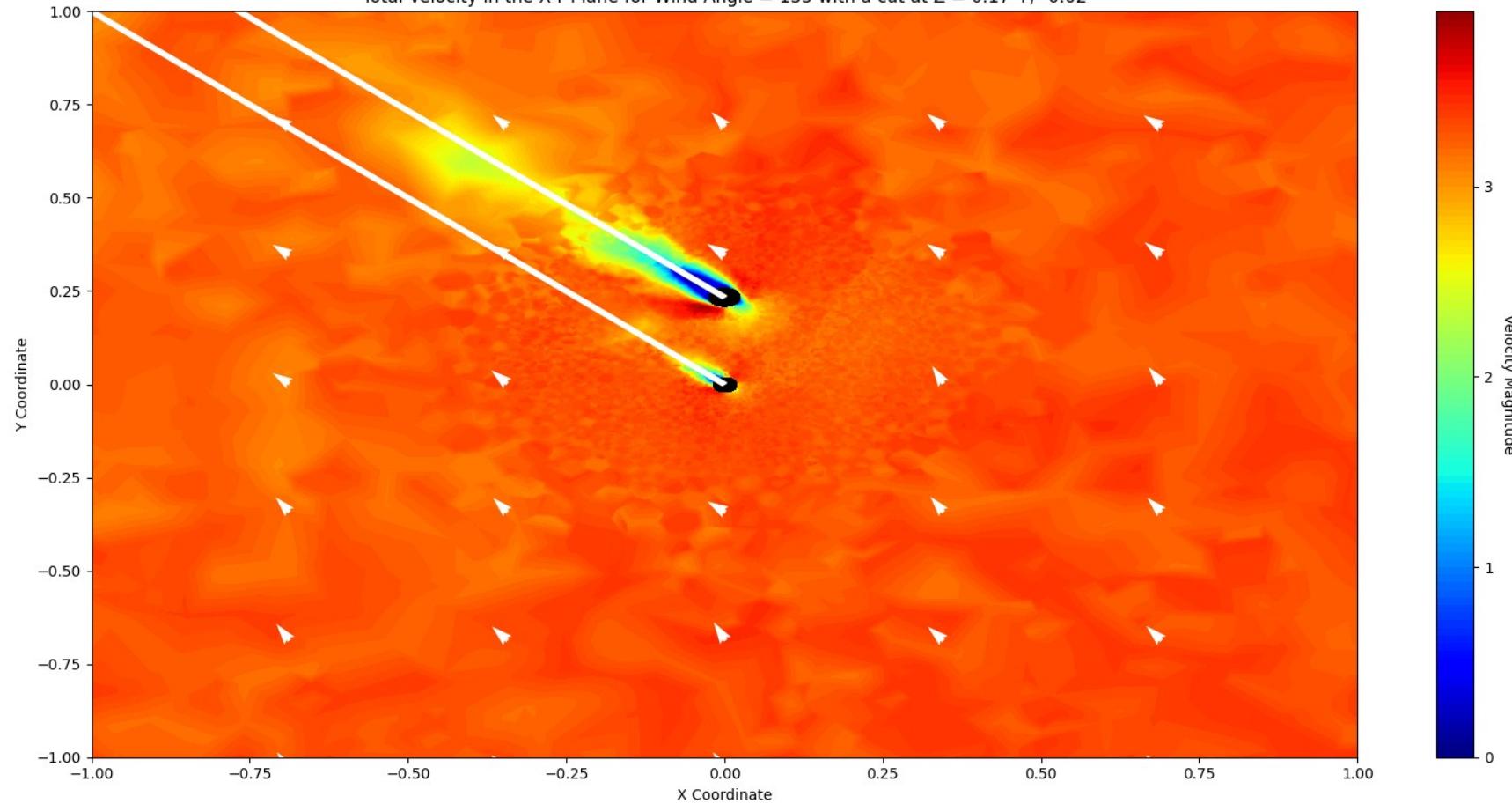
Total Velocity in the X-Y Plane for Wind Angle = 105 with a cut at Z = 0.17 +/- 0.02



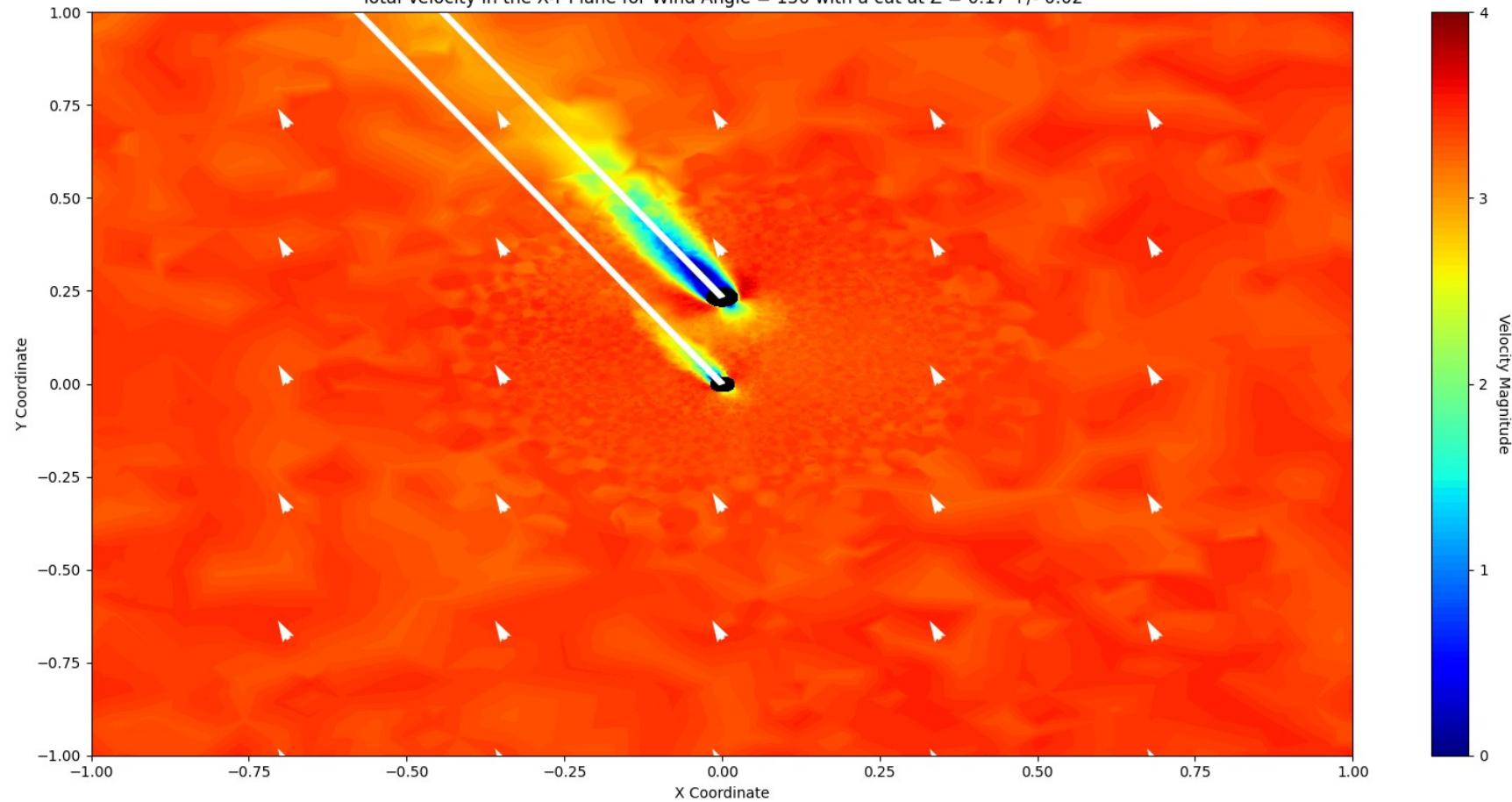
Total Velocity in the X-Y Plane for Wind Angle = 120 with a cut at Z = 0.17 +/- 0.02



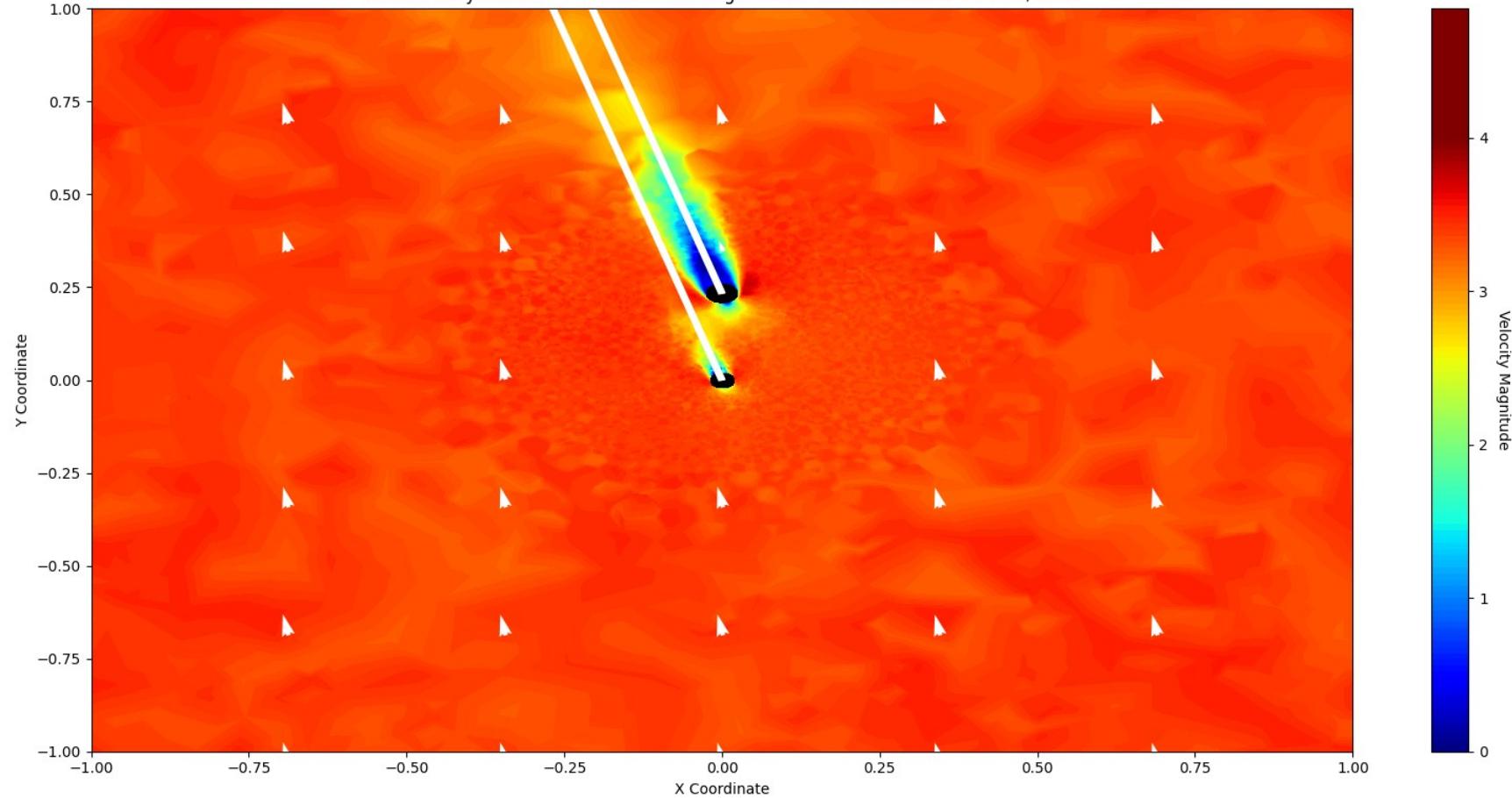
Total Velocity in the X-Y Plane for Wind Angle = 135 with a cut at Z = 0.17 +/- 0.02



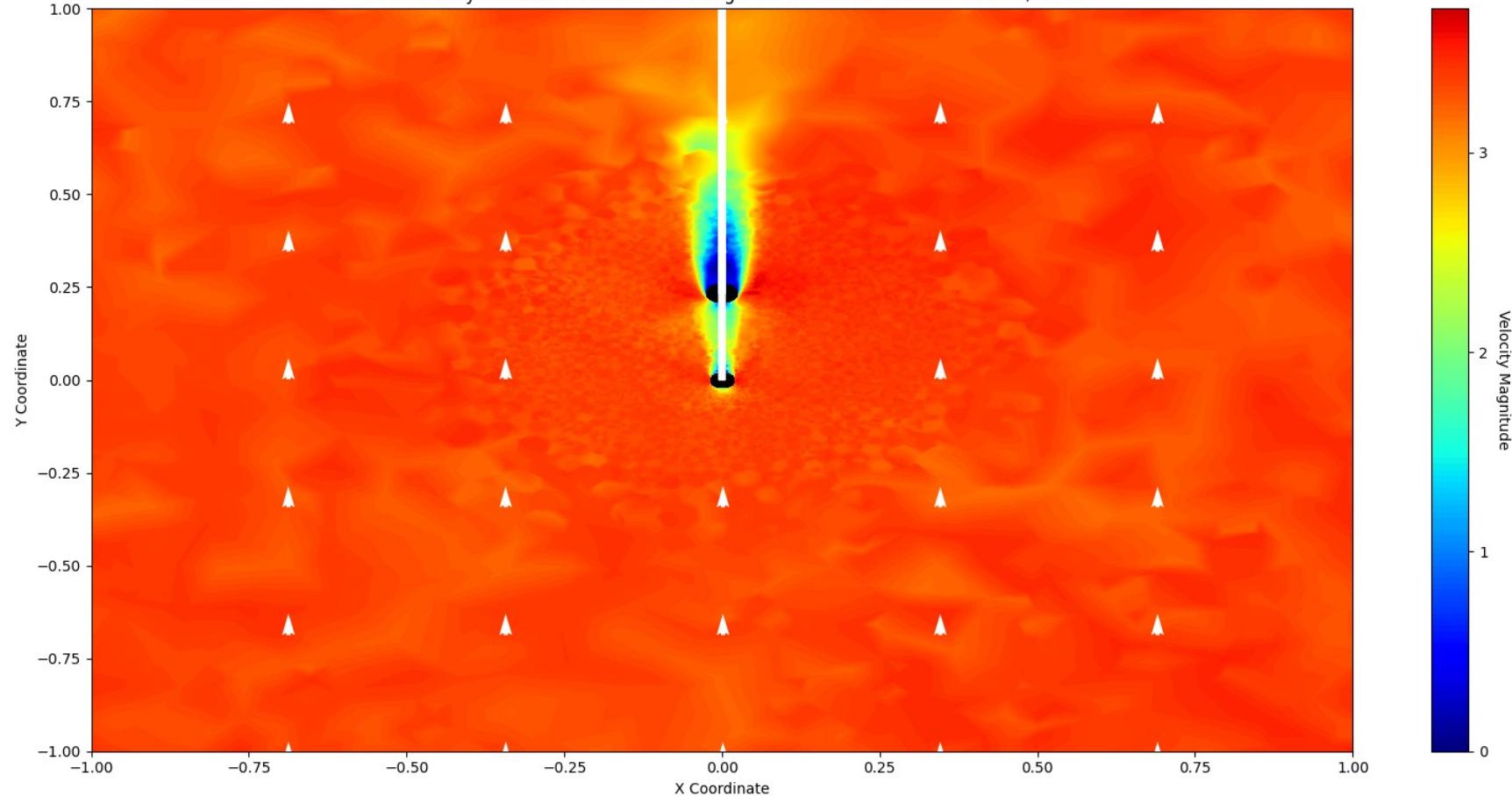
Total Velocity in the X-Y Plane for Wind Angle = 150 with a cut at Z = 0.17 +/- 0.02



Total Velocity in the X-Y Plane for Wind Angle = 165 with a cut at Z = 0.17 +/- 0.02



Total Velocity in the X-Y Plane for Wind Angle = 180 with a cut at Z = 0.17 +/- 0.02

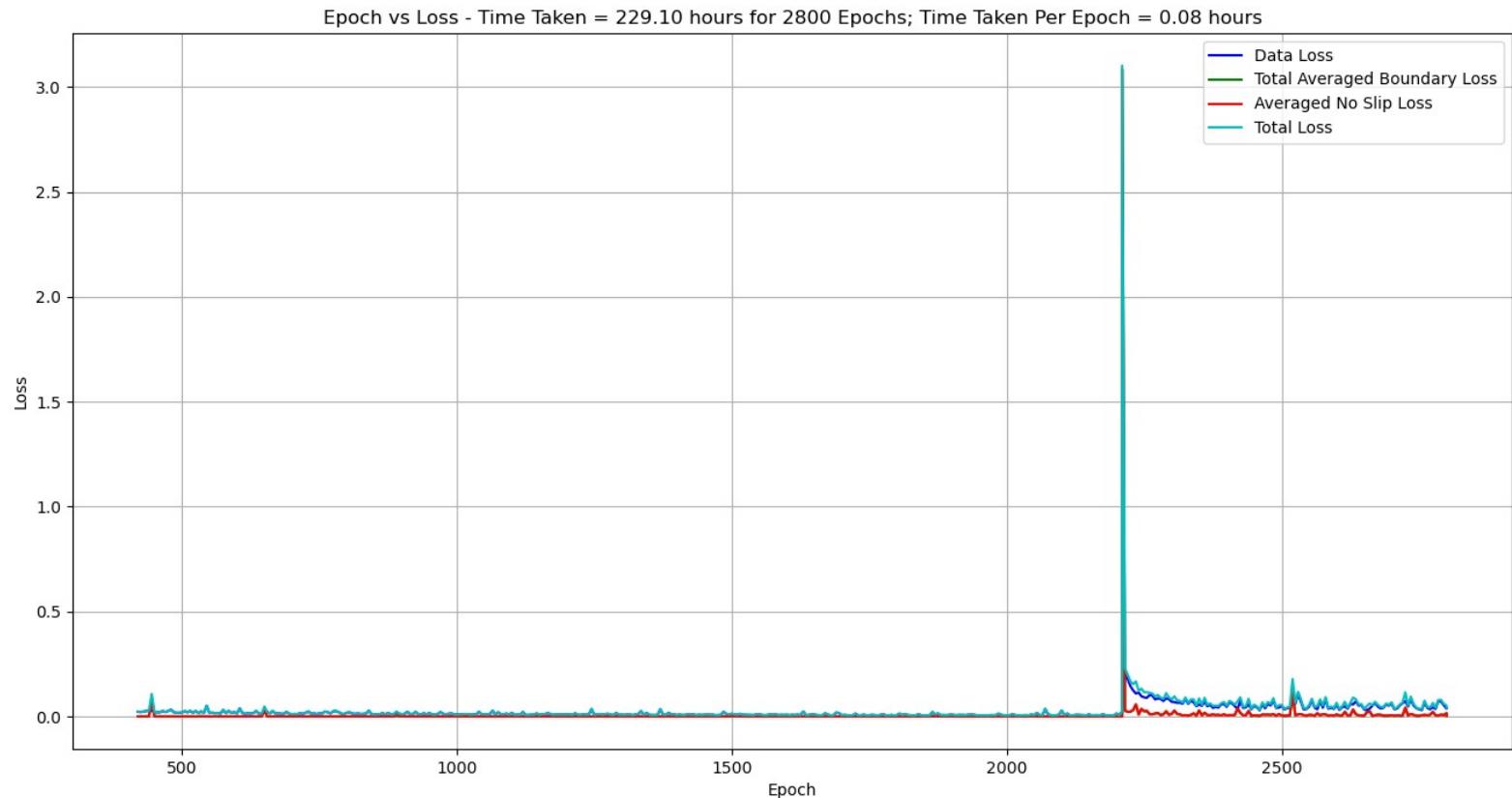


Progress so far - Data + No Slip Loss
Standard Normal Scalar
(Adam Optimizer)

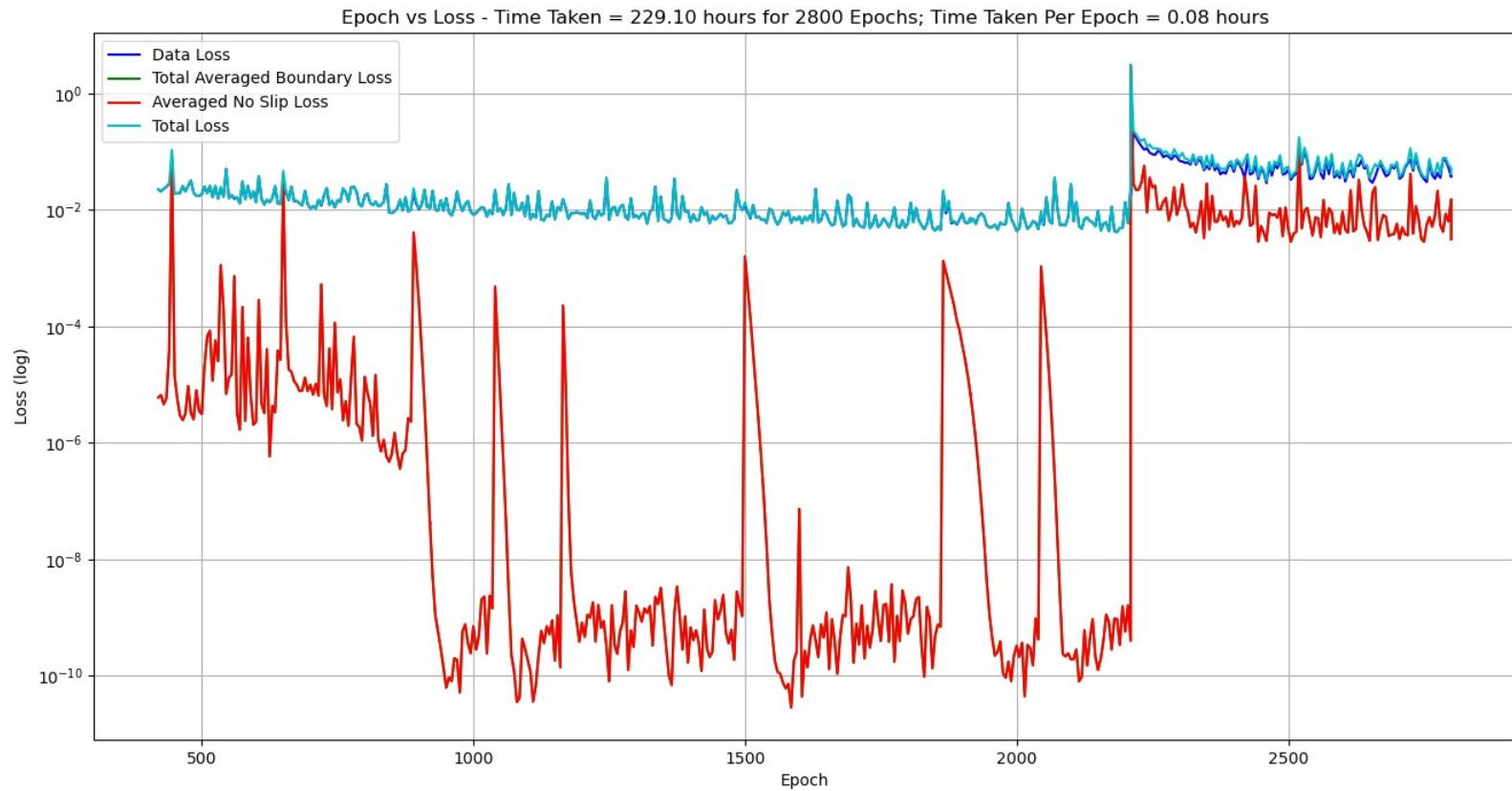
Threshold = 1E-5 (2800 Epochs, not completed), GPU Laptop

Scripts v4 – PREDICTING (135 DEG)

Progress so far - Data Loss + No Slip Loss (Adam Optimizer – Std Normal Scalar)
Logging Plots (Training)

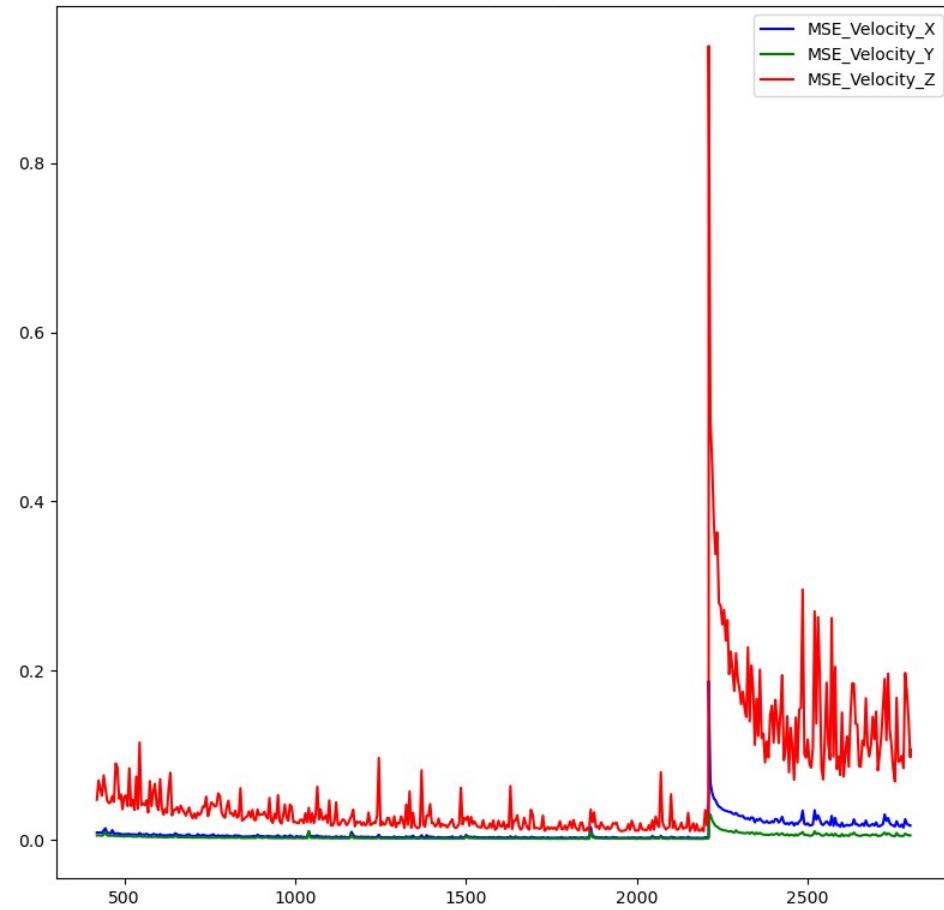


Progress so far - Data Loss + No Slip Loss (Adam Optimizer – Std Normal Scalar)
Logging Plots (Training)

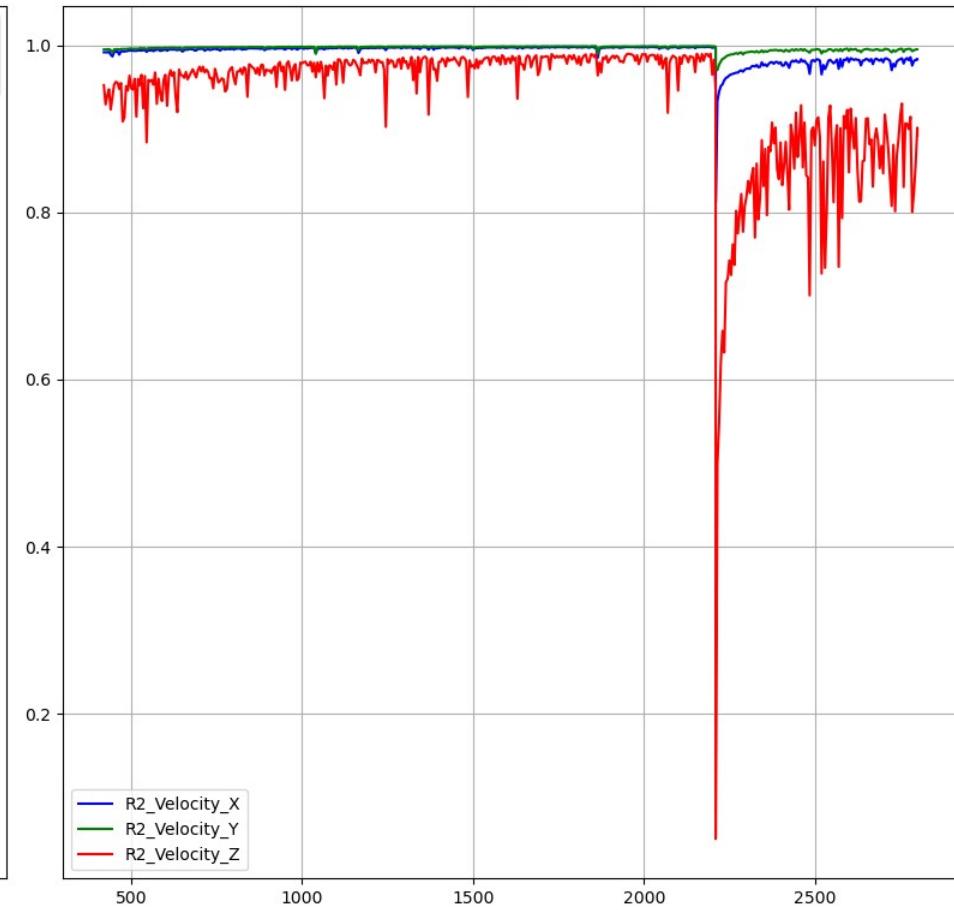


Progress so far - Data Loss + No Slip Loss (Adam Optimizer – Std Normal Scalar)
Logging Plots (Testing)

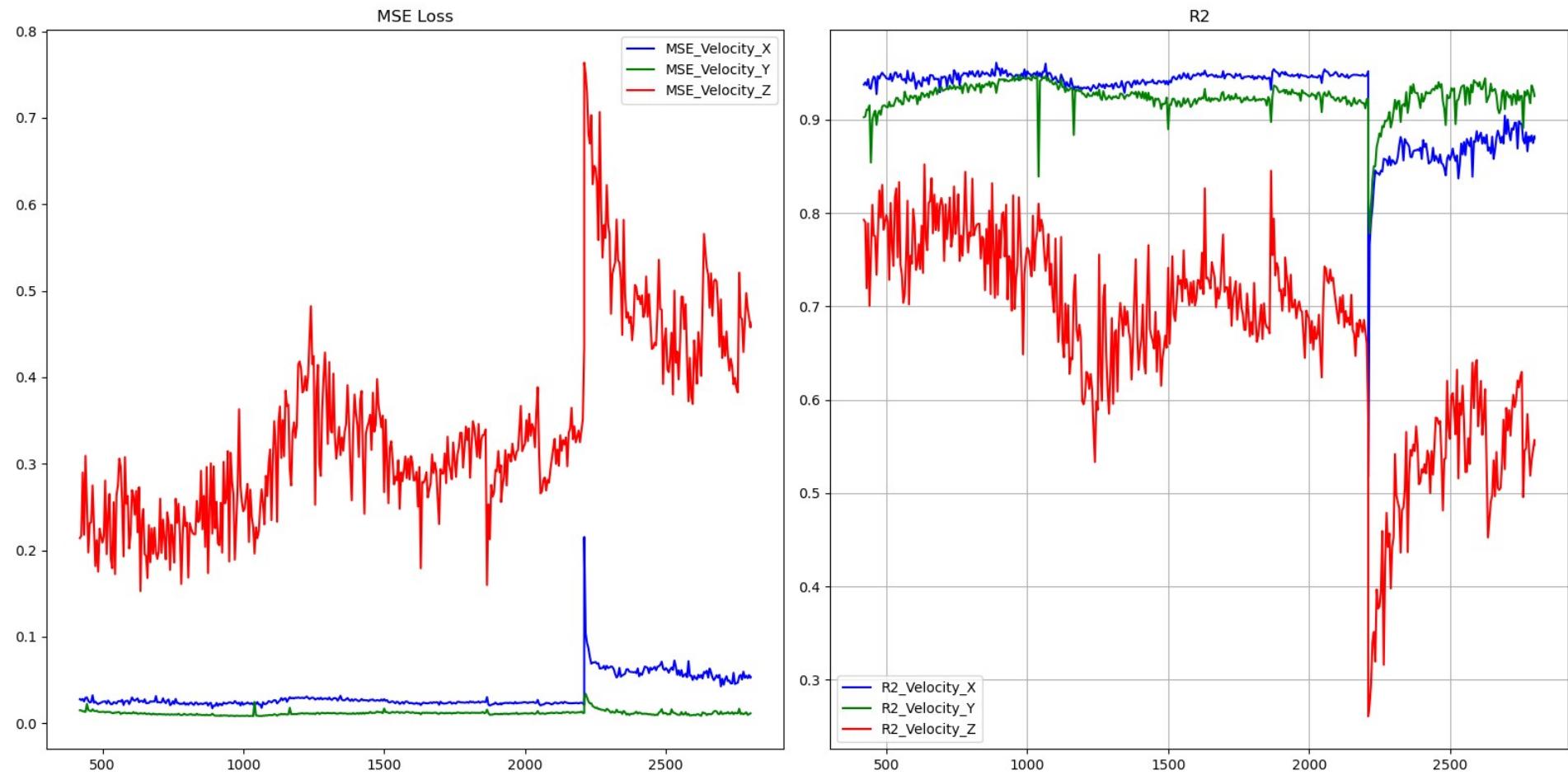
MSE Loss



R2



Progress so far - Data Loss + No Slip Loss (Adam Optimizer – Std Normal Scalar)
Logging Plots (Predicting 135)



Progress so far - Data + No Slip Loss (Adam Optimizer – Std Normal Scalar)
Threshold = 1E-5 (1030 Epochs, so far...), GPU Laptop
Predicting Results – Metrics (Angle = 135)

Variable	MSE	RMSE	MAE	R2
Velocity:0	0.0532236924650972	0.230702606108161	0.111288365128735	0.947780346275545
Velocity:1	0.0572523441479038	0.239274620776847	0.133849165568289	0.944363224955807
Velocity:2	0.0075613956141028 4	0.086956285650336	0.0347438806964828	0.768864041595348

Progress so far - Data + No Slip Loss (Adam Optimizer – Std Normal Scalar)
Threshold = 1E-5 (2280 Epochs, so far...), GPU Laptop
Predicting Results – Metrics (Angle = 135)

Variable	MSE	RMSE	MAE	R2
Velocity:0	0.151526417698636	0.389263943486468	0.201835345647191	0.851332053530129
Velocity:1	0.10155159282282	0.318671606552607	0.199819511535255	0.901314029855849
Velocity:2	0.0182379773874412	0.13504805584473	0.0428812395102974	0.442503395147542

Progress so far - Data + No Slip Loss (Adam Optimizer – Std Normal Scalar)
Threshold = 1E-5 (2430 Epochs, so far...), GPU Laptop
Predicting Results – Metrics (Angle = 135)

Variable	MSE	RMSE	MAE	R2
Velocity:0	0.148327560797495	0.38513317280844	0.200360167839942	0.85447056557157
Velocity:1	0.0739678487230551	0.271970308532117	0.157111667630288	0.928119405045214
Velocity:2	0.0163550181550284	0.127886739558988	0.0387504523786084	0.500061498047079

Progress so far - Data + No Slip Loss (Adam Optimizer – Std Normal Scalar)
Threshold = 1E-5 (2645 Epochs, so far...), GPU Laptop
Predicting Results – Metrics (Angle = 135)

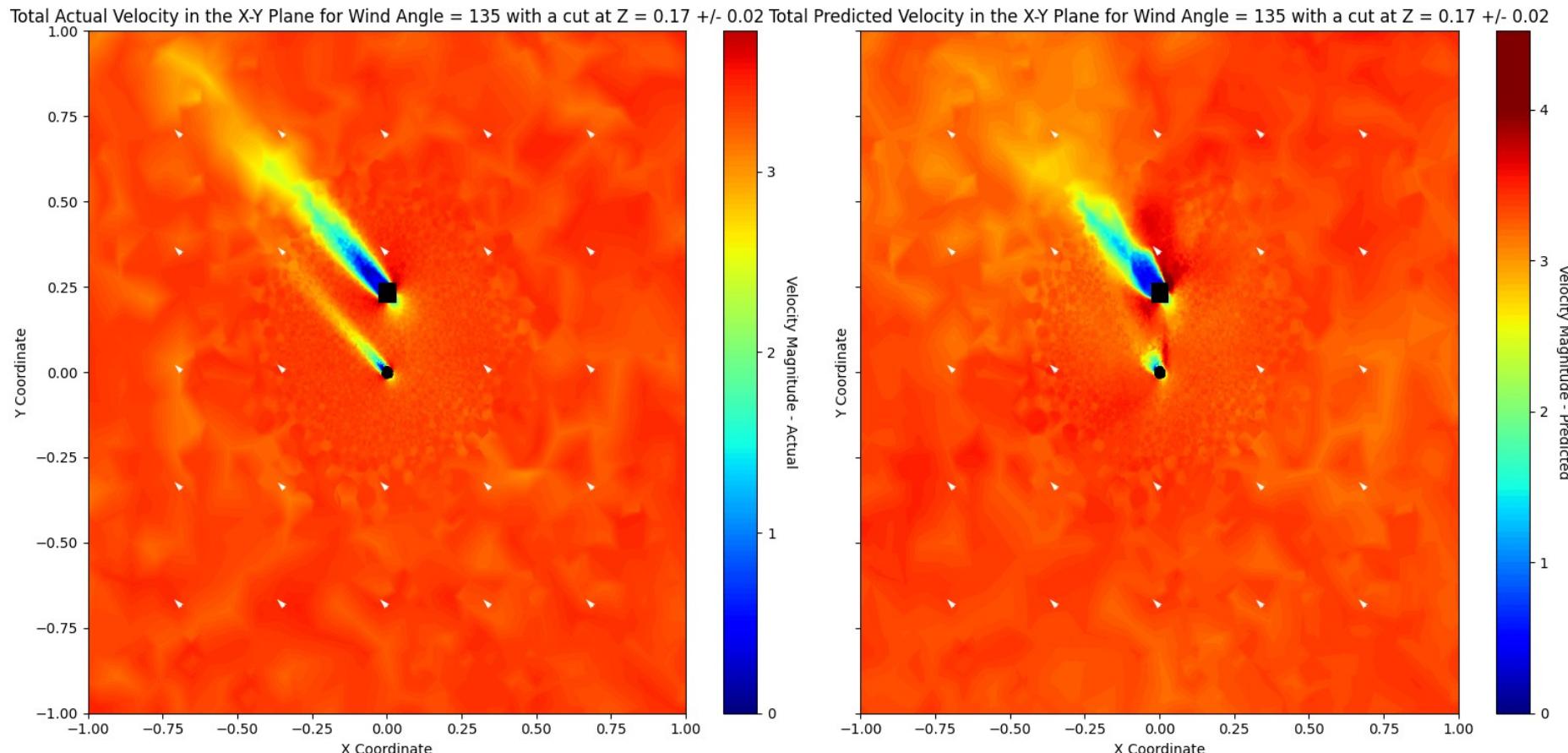
Variable	MSE	RMSE	MAE	R2
Velocity:0	0.138575771721025	0.372257668451605	0.186844100846197	0.864038391950793
Velocity:1	0.0630614153636948	0.251120320491383	0.14677190355298	0.938718076390122
Velocity:2	0.0166670142871756	0.129100791195002	0.0399814221115995	0.490524432576268

Progress so far - Data + No Slip Loss (Adam Optimizer – Std Normal Scalar)
Threshold = 1E-5 (2800 Epochs, so far...), GPU Laptop
Predicting Results – Metrics (Angle = 135)

Variable	MSE	RMSE	MAE	R2
Velocity:0	0.119675957774848	0.345942130673395	0.167227668203061	0.882581670216824
Velocity:1	0.0760898068173541	0.27584380873486	0.14682741033562	0.926057325196732
Velocity:2	0.0144883099550827	0.120367395731081	0.0357886344997361	0.557122841068402

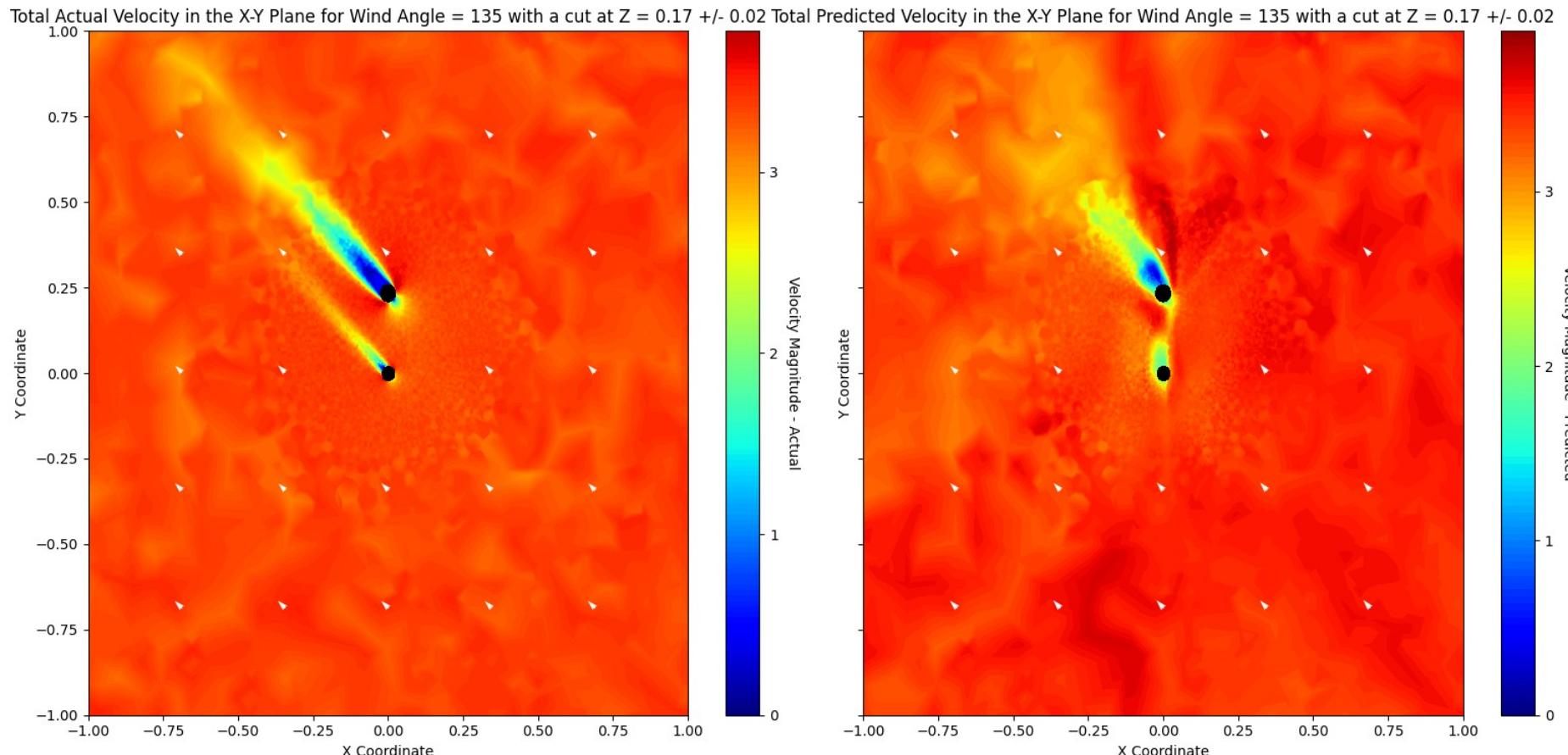
Progress so far - Data + No Slip Loss (Adam Optimizer – Std Normal Scalar), Threshold = 1E-5 (1030 Epochs, so far...), GPU Laptop
Predicting Results - X-Y Total Velocity Plot (Angle = 135)

Comparison of Actual vs. Predicted values with Wind Angle = 135 in the X-Y Plane with a cut at Z = 0.17 +/- 0.02

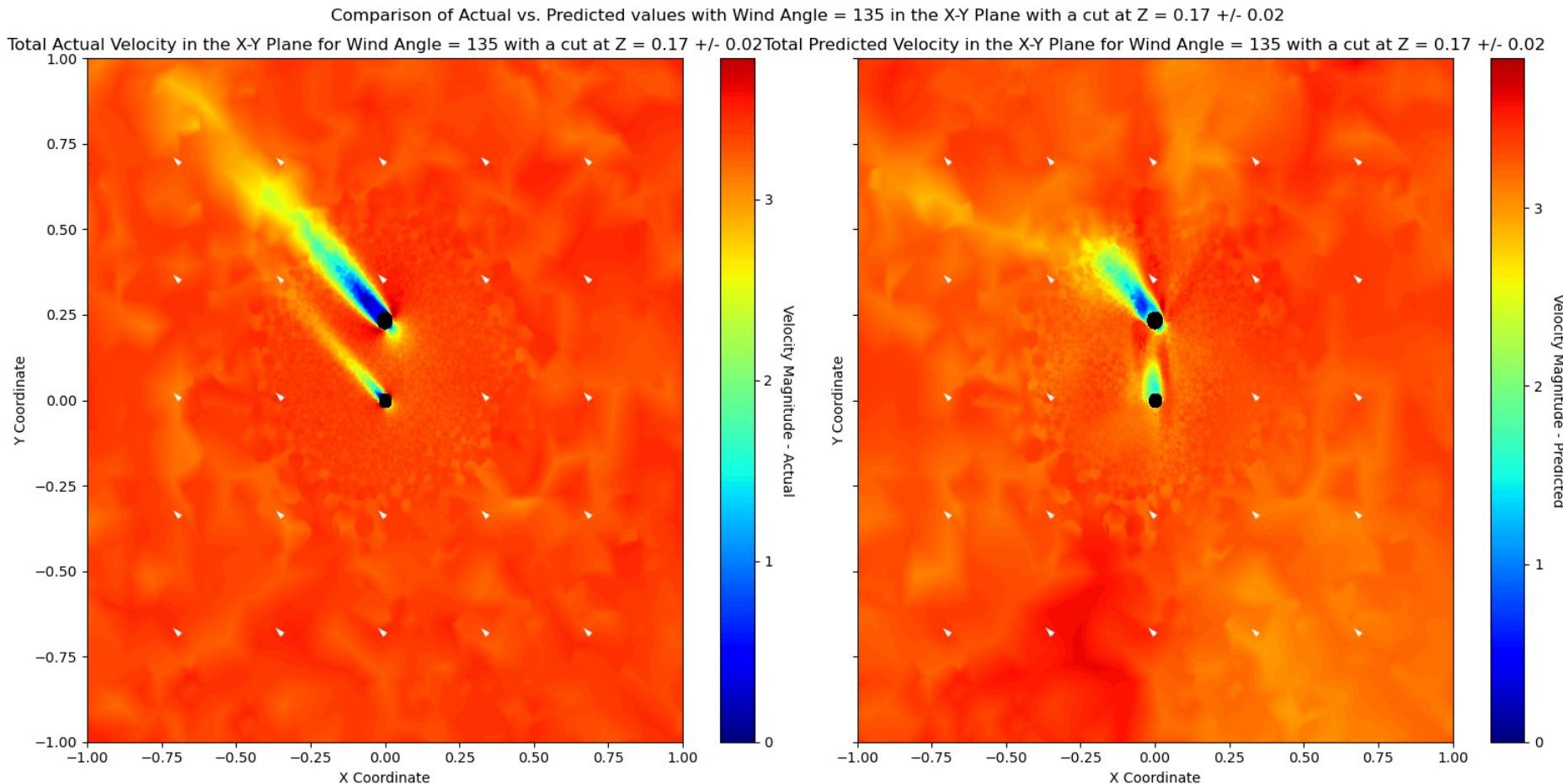


Progress so far - Data + No Slip Loss (Adam Optimizer – Std Normal Scalar), Threshold = 1E-5 (2280 Epochs, so far...), GPU Laptop
Predicting Results - X-Y Total Velocity Plot (Angle = 135)

Comparison of Actual vs. Predicted values with Wind Angle = 135 in the X-Y Plane with a cut at Z = 0.17 +/- 0.02

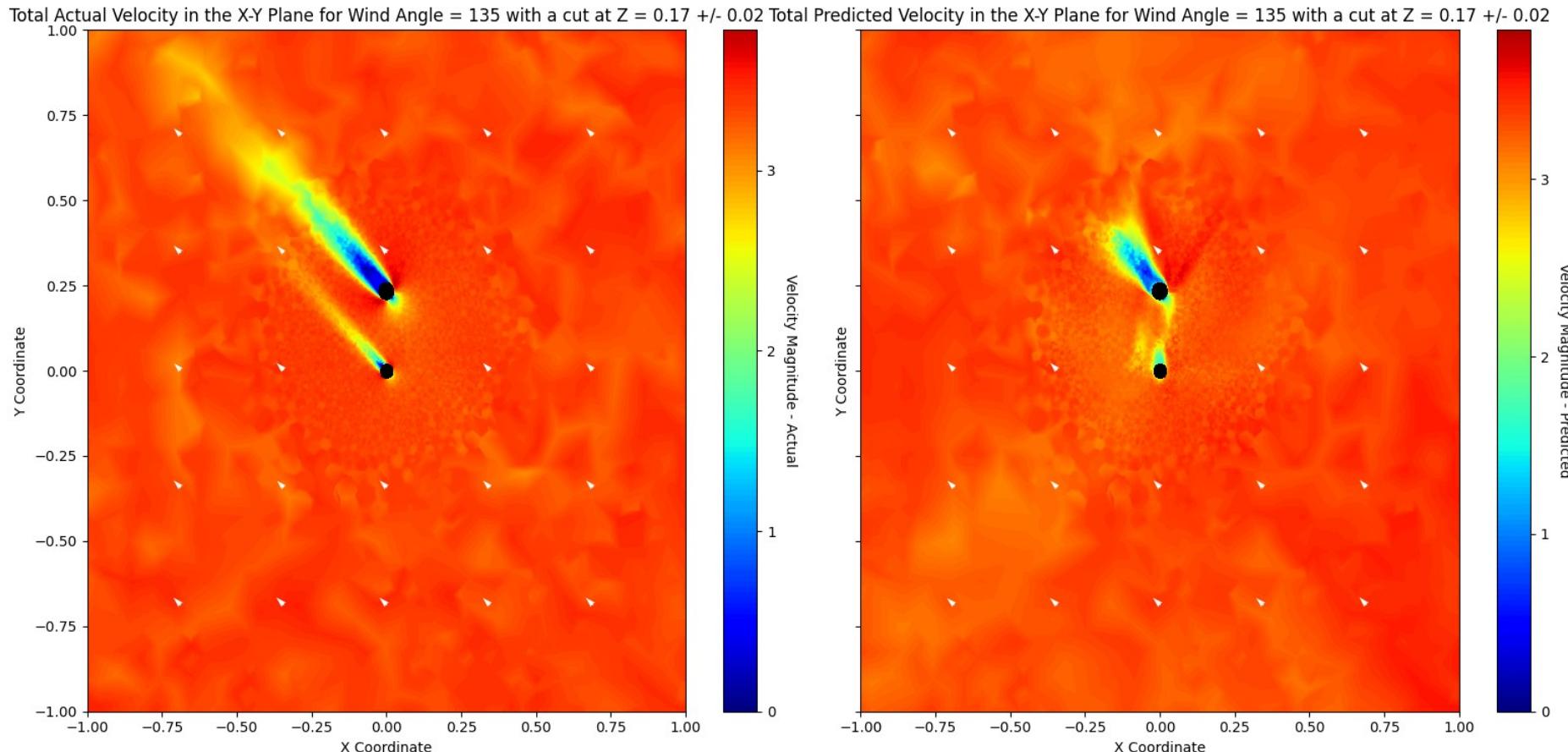


Progress so far - Data + No Slip Loss (Adam Optimizer – Std Normal Scalar), Threshold = 1E-5 (2430 Epochs, so far...), GPU Laptop
Predicting Results - X-Y Total Velocity Plot (Angle = 135)

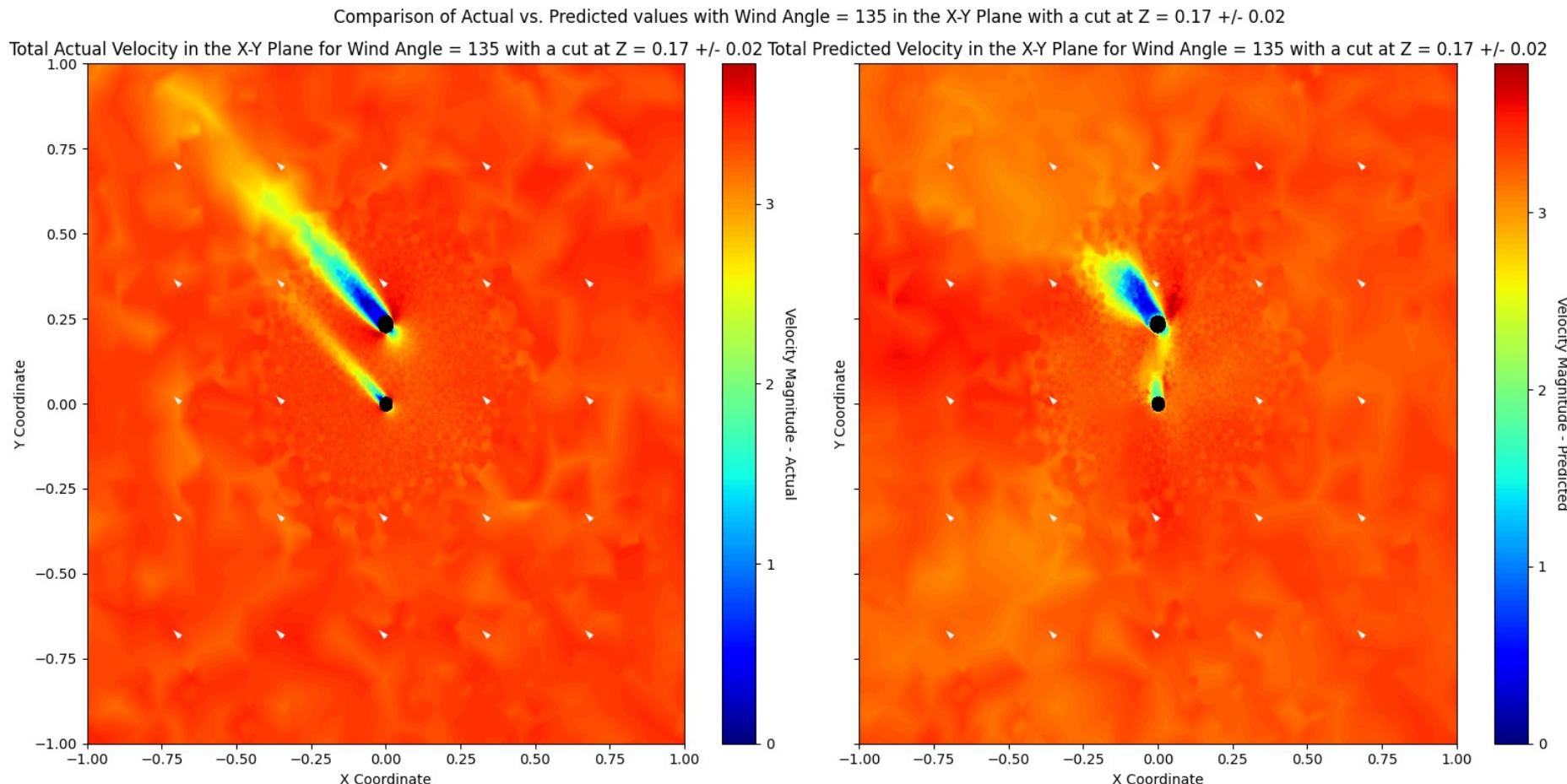


Progress so far - Data + No Slip Loss (Adam Optimizer – Std Normal Scalar), Threshold = 1E-5 (2645 Epochs, so far...), GPU Laptop
Predicting Results - X-Y Total Velocity Plot (Angle = 135)

Comparison of Actual vs. Predicted values with Wind Angle = 135 in the X-Y Plane with a cut at Z = 0.17 +/- 0.02



Progress so far - Data + No Slip Loss (Adam Optimizer – Std Normal Scalar), Threshold = 1E-5 (2800 Epochs, so far...), GPU Laptop
Predicting Results - X-Y Total Velocity Plot (Angle = 135)

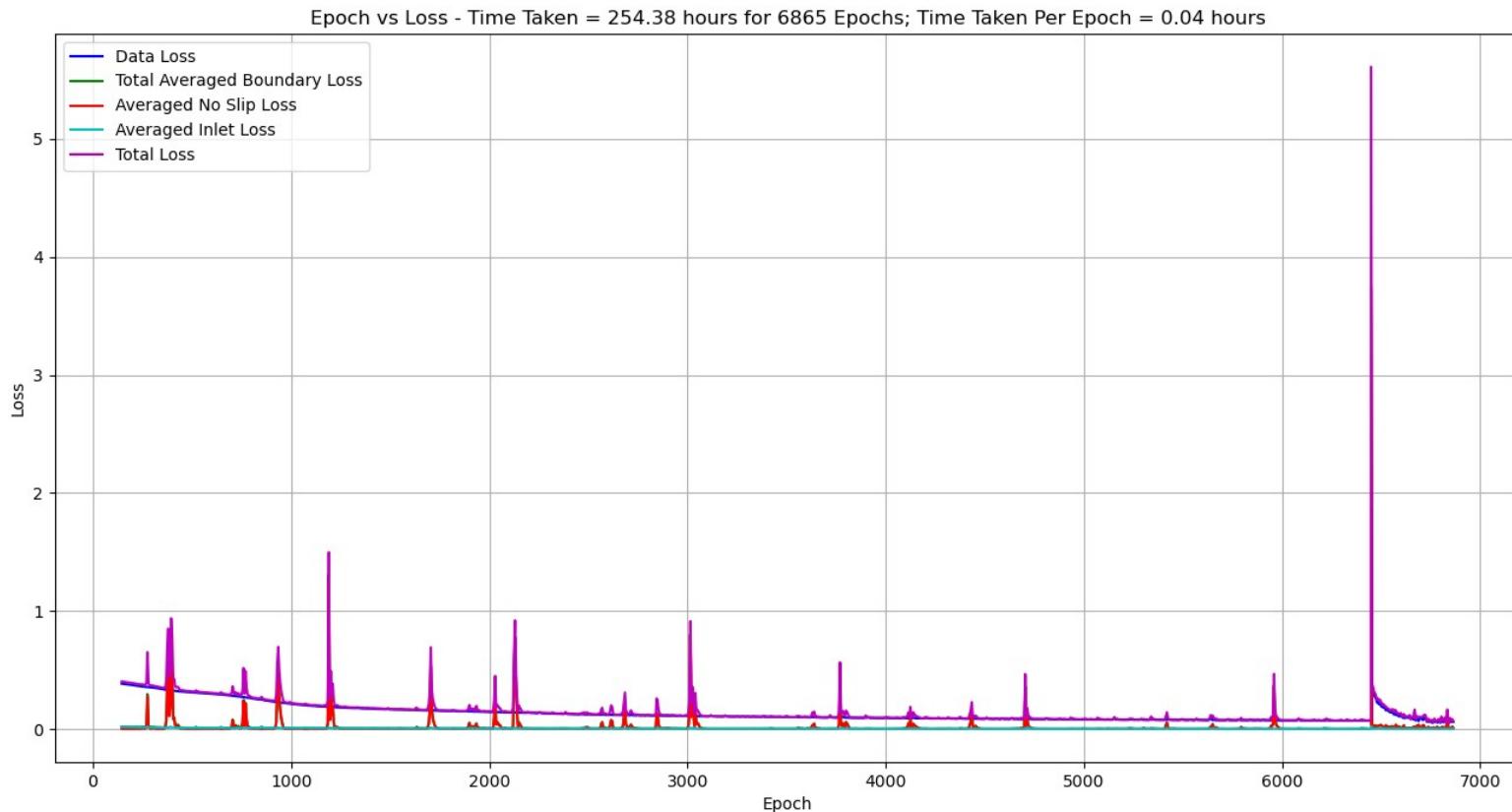


Progress so far - Data + No Slip + Inlet Loss
Standard Normal Scalar
(Adam Optimizer)

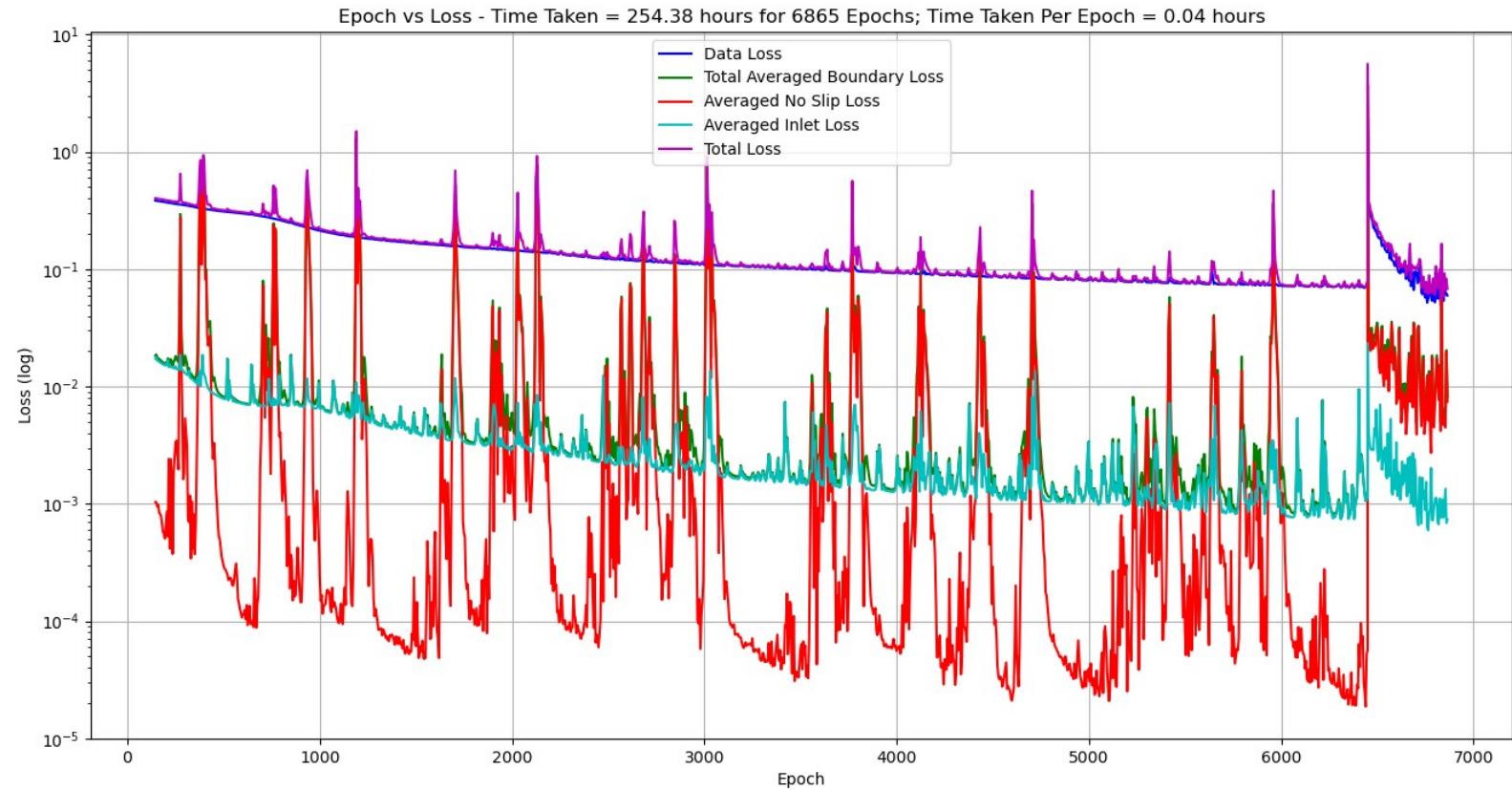
Threshold = 1E-5 (6865 Epochs, not completed), GPU Workstation

Scripts v4 – PREDICTING (135 DEG)

Progress so far - Data Loss + No Slip + Inlet Loss (Adam Optimizer – Std Normal Scalar)
Logging Plots (Training)

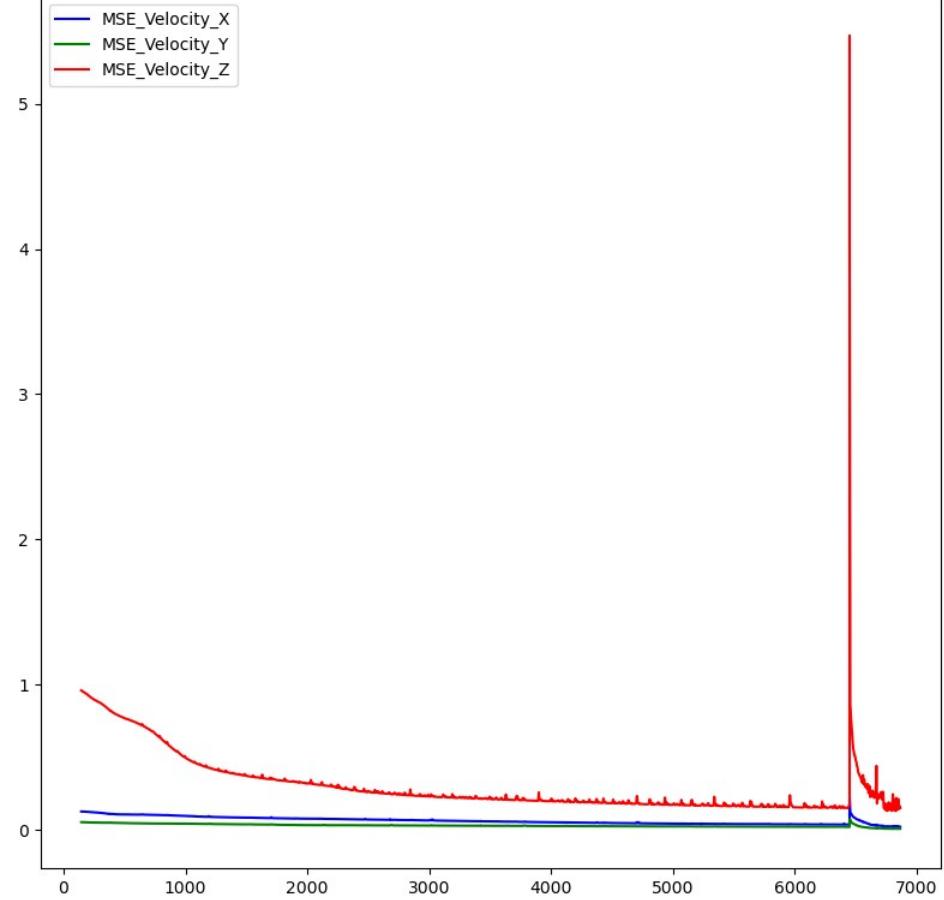


Progress so far - Data Loss + No Slip + Inlet Loss (Adam Optimizer – Std Normal Scalar)
Logging Plots (Training)

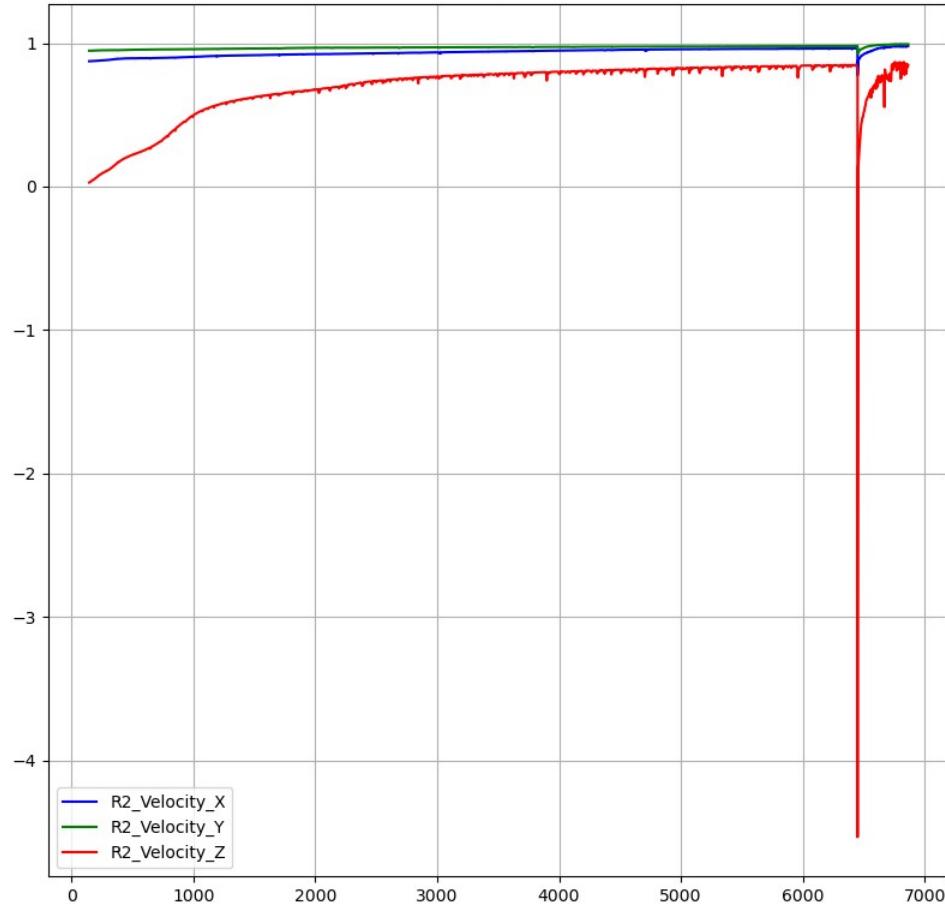


Progress so far - Data Loss + No Slip + Inlet Loss (Adam Optimizer – Std Normal Scalar)
Logging Plots (Testing)

MSE Loss

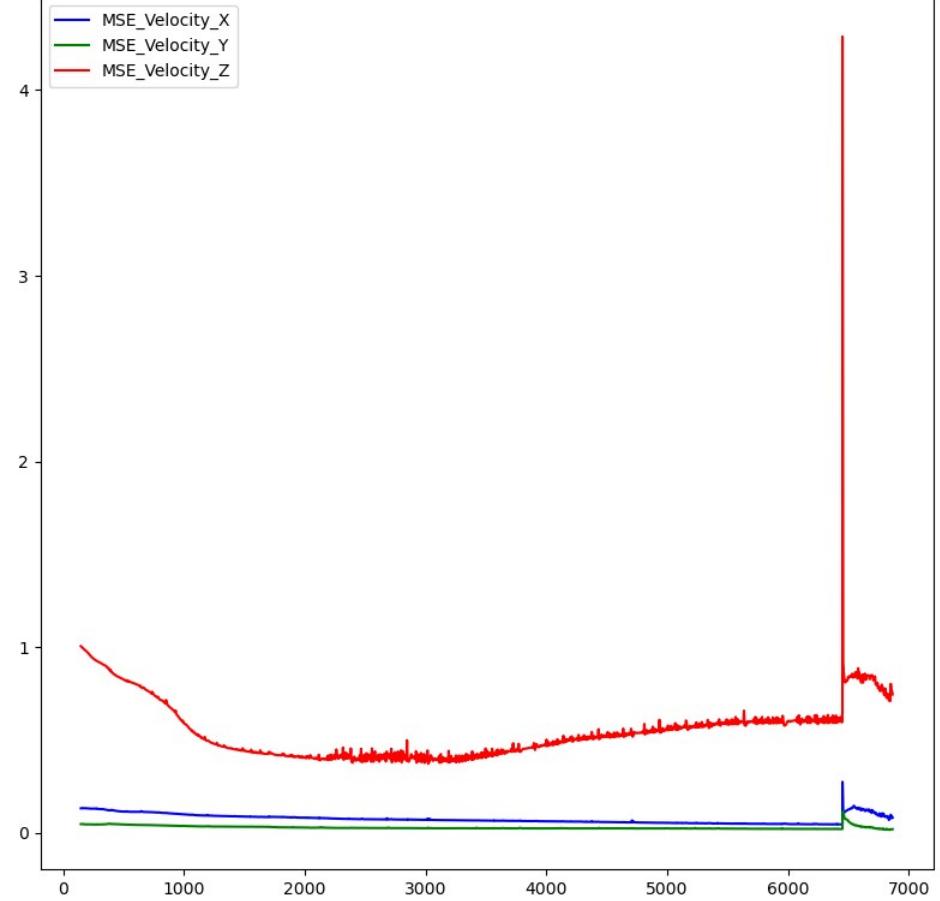


R2

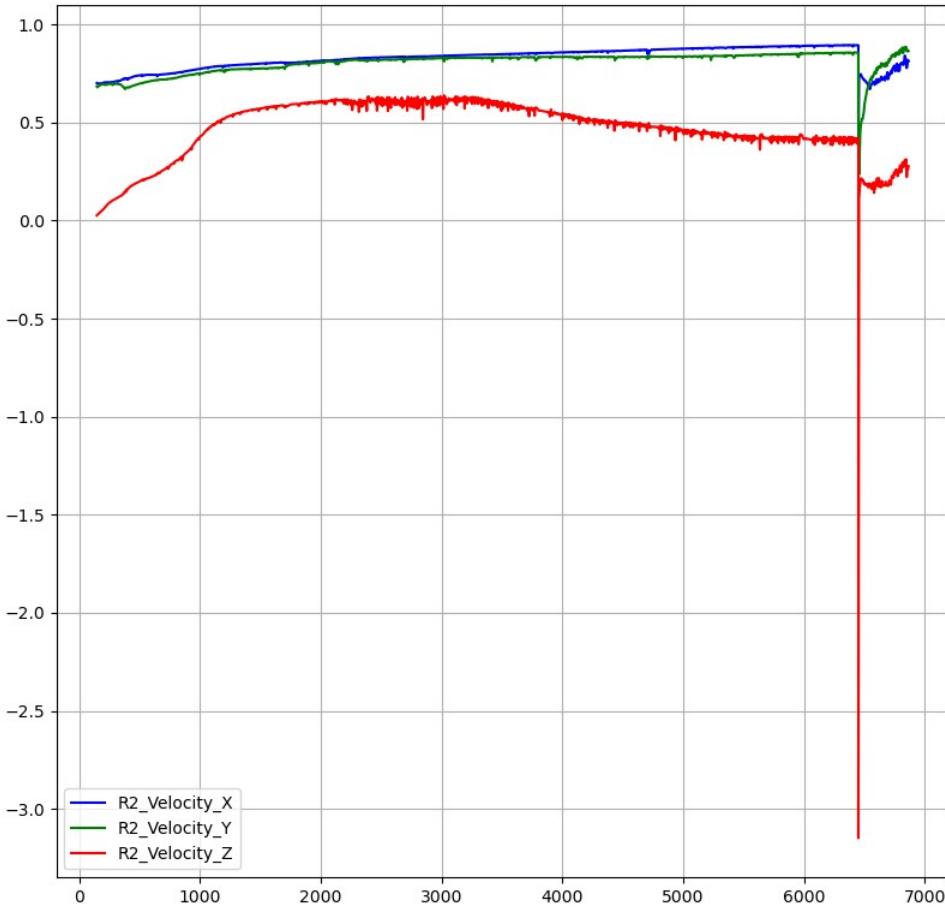


Progress so far - Data Loss + No Slip + Inlet Loss (Adam Optimizer – Std Normal Scalar)
Logging Plots (Predicting 135)

MSE Loss



R2



Progress so far - Data + No Slip + Inlet Loss (Adam Optimizer – Std Normal Scalar)
Threshold = 1E-5 (2215 Epochs, so far...), GPU Workstation
Predicting Results – Metrics (Angle = 135)

Variable	MSE	RMSE	MAE	R2
Velocity:0	0.180166510802504	0.424460258213304	0.241915616710653	0.823232241674705
Velocity:1	0.189689449807947	0.43553352317353	0.266575881972611	0.815663281490145
Velocity:2	0.0126651486614695	0.112539542657101	0.0523497251641134	0.612853046764769

Progress so far - Data + No Slip + Inlet Loss (Adam Optimizer – Std Normal Scalar)
Threshold = 1E-5 (3210 Epochs, so far...), GPU Workstation
Predicting Results – Metrics (Angle = 135)

Variable	MSE	RMSE	MAE	R2
Velocity:0	0.159096535042105	0.39886907004944	0.217568217575201	0.843904742721344
Velocity:1	0.173759832634877	0.416845094291485	0.256031913781074	0.831143390477625
Velocity:2	0.0131650341132649	0.114738982535426	0.0517943925913786	0.59757260002055

Progress so far - Data + No Slip + Inlet Loss (Adam Optimizer – Std Normal Scalar)
Threshold = 1E-5 (3720 Epochs, so far...), GPU Workstation
Predicting Results – Metrics (Angle = 135)

Variable	MSE	RMSE	MAE	R2
Velocity:0	0.154020450821566	0.392454393301394	0.223505571086462	0.848885069113516
Velocity:1	0.174235993541251	0.417415852048351	0.251219541141501	0.830680666066475
Velocity:2	0.0151169623727251	0.122951056818252	0.0553607325531714	0.537906259041645

Progress so far - Data + No Slip + Inlet Loss (Adam Optimizer – Std Normal Scalar)
Threshold = 1E-5 (6580 Epochs, so far...), GPU Workstation
Predicting Results – Metrics (Angle = 135)

Variable	MSE	RMSE	MAE	R2
Velocity:0	0.298503703077158	0.546354924089788	0.263440700896321	0.707127422240033
Velocity:1	0.257972543080475	0.50790997537012	0.293448629293877	0.749307027326806
Velocity:2	0.0280835379832291	0.167581436869449	0.0621267824950149	0.141545318030913

Progress so far - Data + No Slip + Inlet Loss (Adam Optimizer – Std Normal Scalar)
Threshold = 1E-5 (6720 Epochs, so far...), GPU Workstation
Predicting Results – Metrics (Angle = 135)

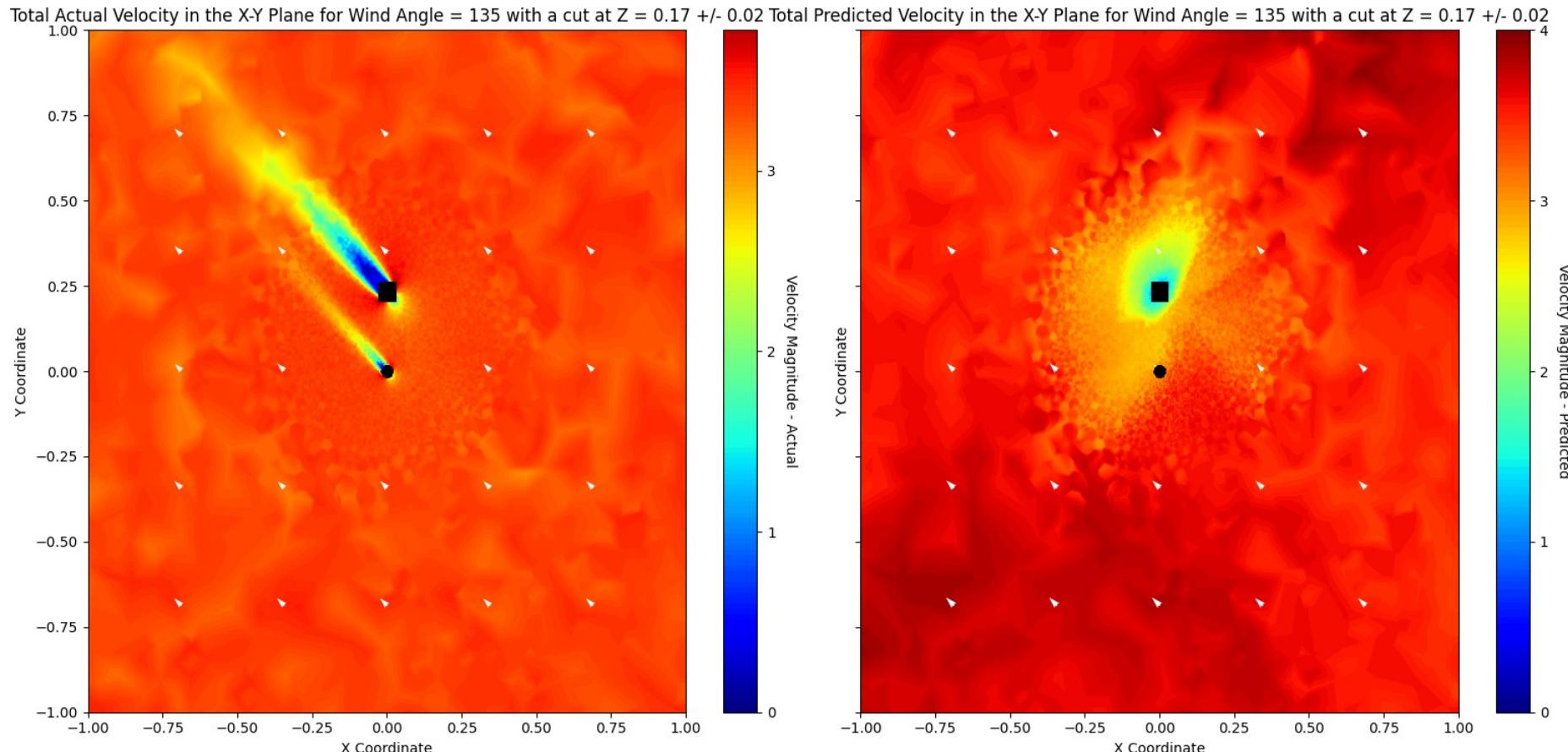
Variable	MSE	RMSE	MAE	R2
Velocity:0	0.241960197992863	0.491894498843871	0.238081619957912	0.762604261953946
Velocity:1	0.172578611503787	0.415425819495836	0.22675474680872	0.832291279447518
Velocity:2	0.0267255230307008	0.163479426934097	0.0583304061039796	0.183056978523196

Progress so far - Data + No Slip + Inlet Loss (Adam Optimizer – Std Normal Scalar)
Threshold = 1E-5 (6720 Epochs, so far...), GPU Workstation
Predicting Results – Metrics (Angle = 135)

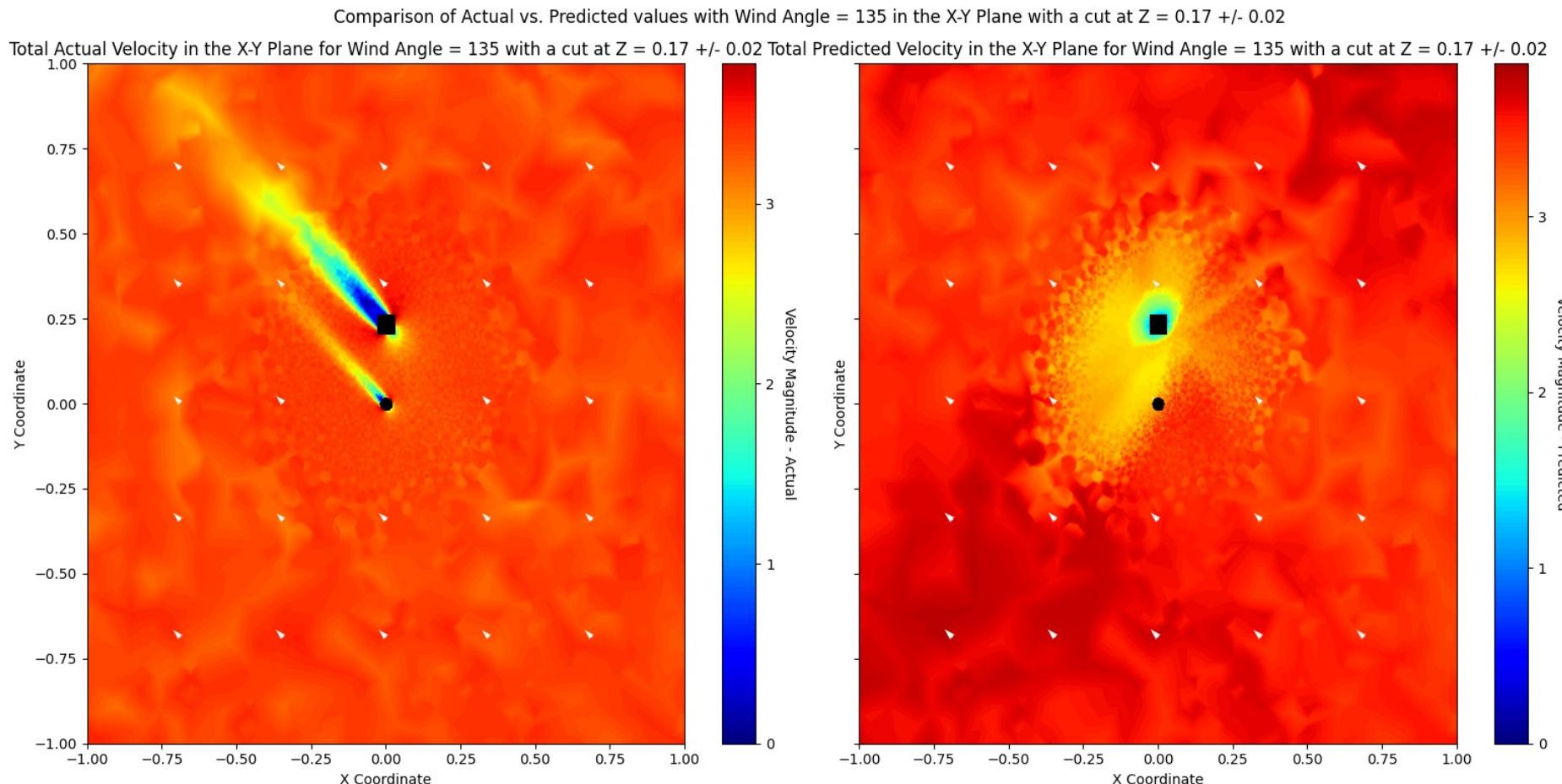
Variable	MSE	RMSE	MAE	R2
Velocity:0	0.180673847269942	0.425057463491635	0.208625794252188	0.822734475859815
Velocity:1	0.117356614412587	0.342573516799806	0.195139623424994	0.885955000564632
Velocity:2	0.0224994997999018	0.149998332657072	0.0516504870773602	0.312237619180225

Progress so far - Data + No Slip + Inlet Loss (Adam Optimizer – Std Normal Scalar), Threshold = 1E-5 (2215 Epochs, so far...), GPU Workstation
Predicting Results - X-Y Total Velocity Plot (Angle = 135)

Comparison of Actual vs. Predicted values with Wind Angle = 135 in the X-Y Plane with a cut at Z = 0.17 +/- 0.02

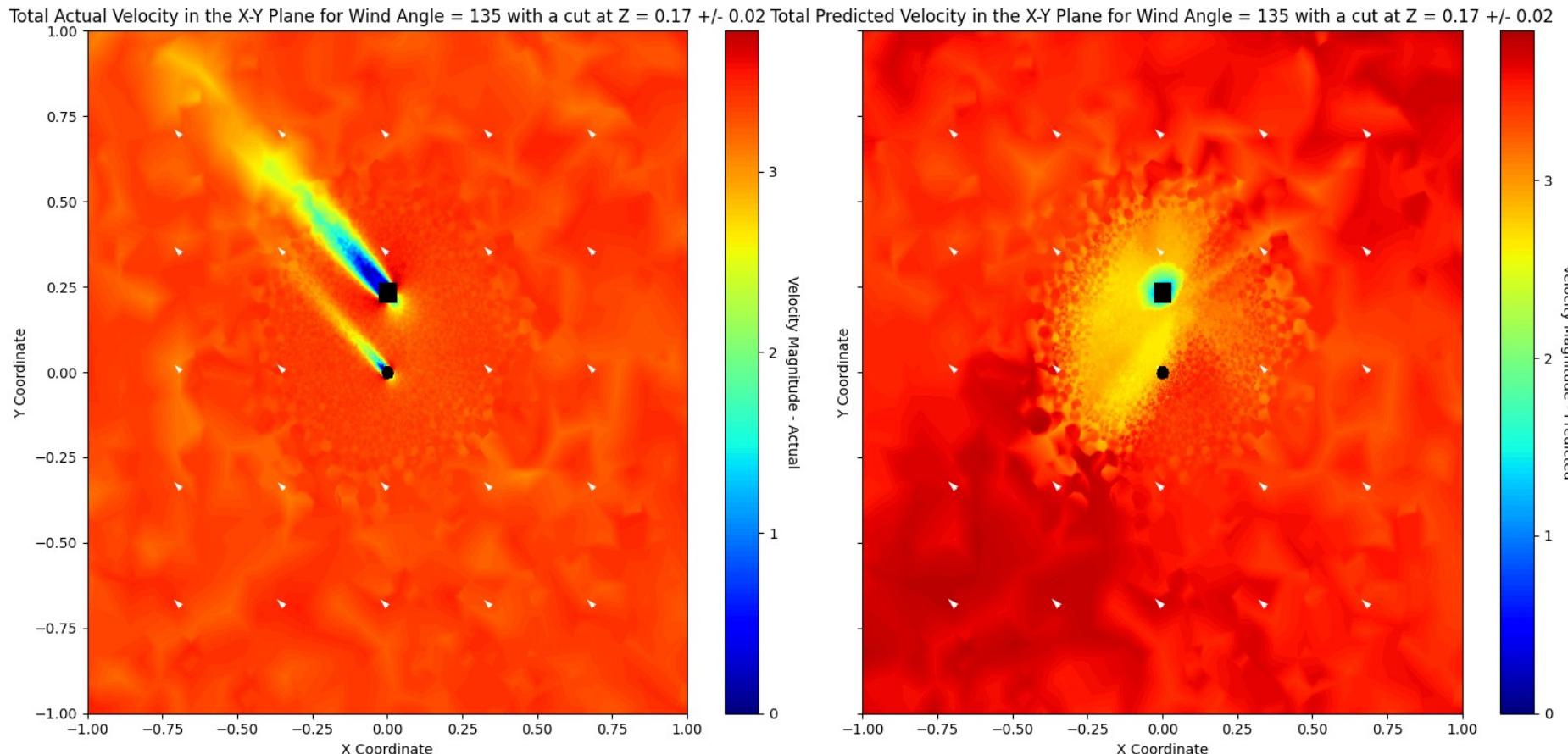


Progress so far - Data + No Slip + Inlet Loss (Adam Optimizer – Std Normal Scalar), Threshold = 1E-5 (3210 Epochs, so far...), GPU Workstation
Predicting Results - X-Y Total Velocity Plot (Angle = 135)

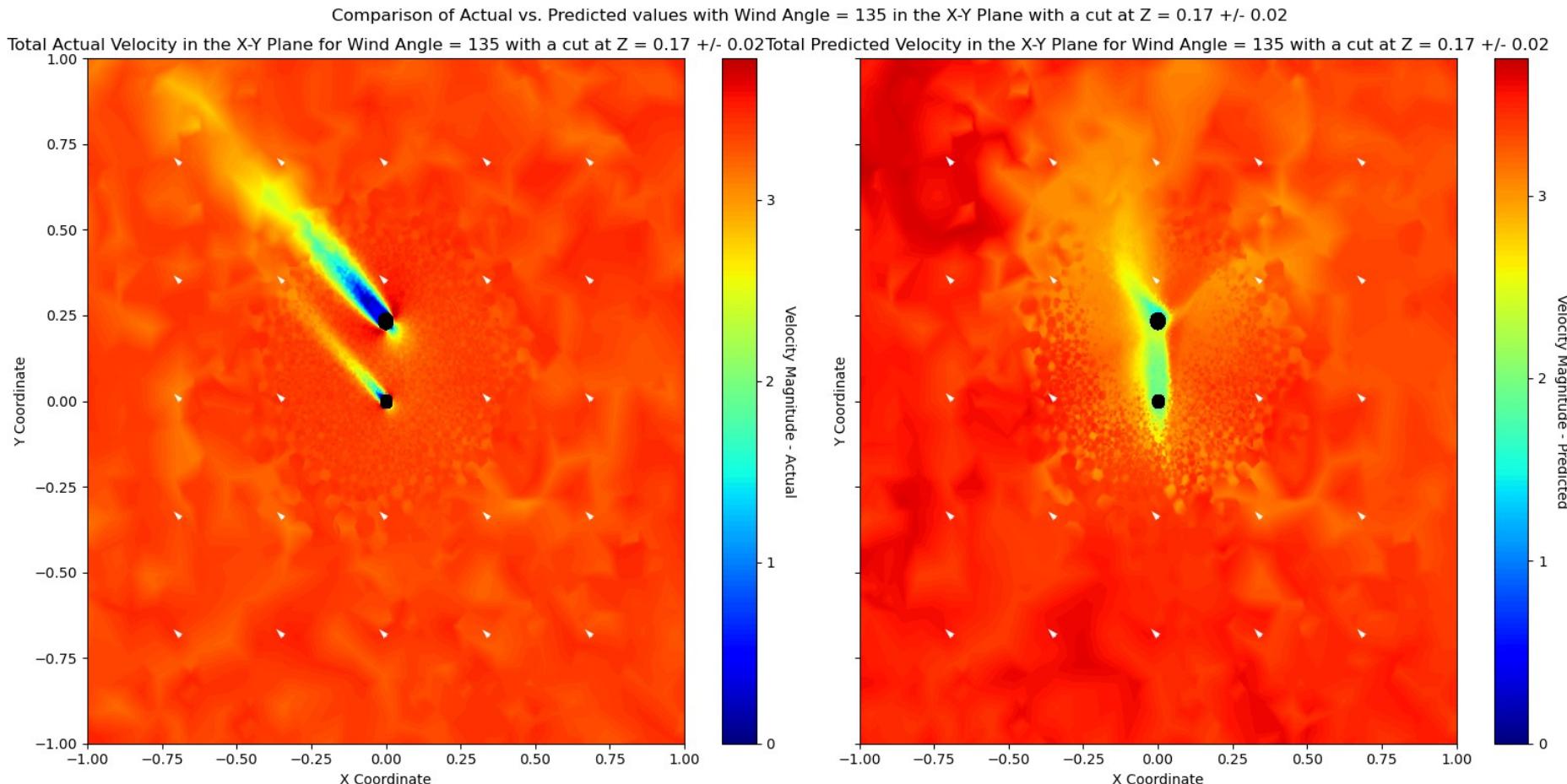


Progress so far - Data + No Slip + Inlet Loss (Adam Optimizer – Std Normal Scalar), Threshold = 1E-5 (3720 Epochs, so far...), GPU Workstation
Predicting Results - X-Y Total Velocity Plot (Angle = 135)

Comparison of Actual vs. Predicted values with Wind Angle = 135 in the X-Y Plane with a cut at Z = 0.17 +/- 0.02

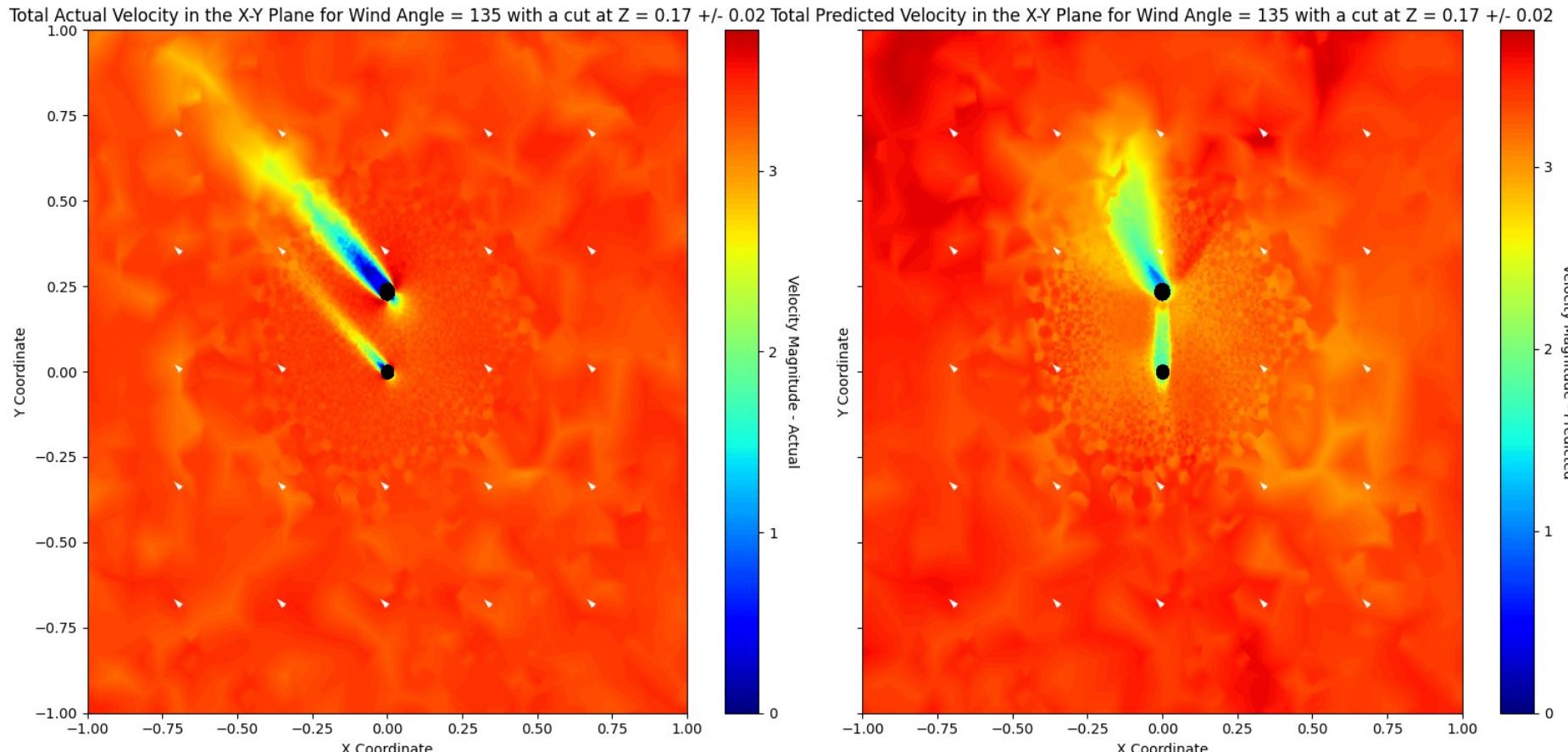


Progress so far - Data + No Slip + Inlet Loss (Adam Optimizer – Std Normal Scalar), Threshold = 1E-5 (6580 Epochs, so far...), GPU Workstation
Predicting Results - X-Y Total Velocity Plot (Angle = 135)



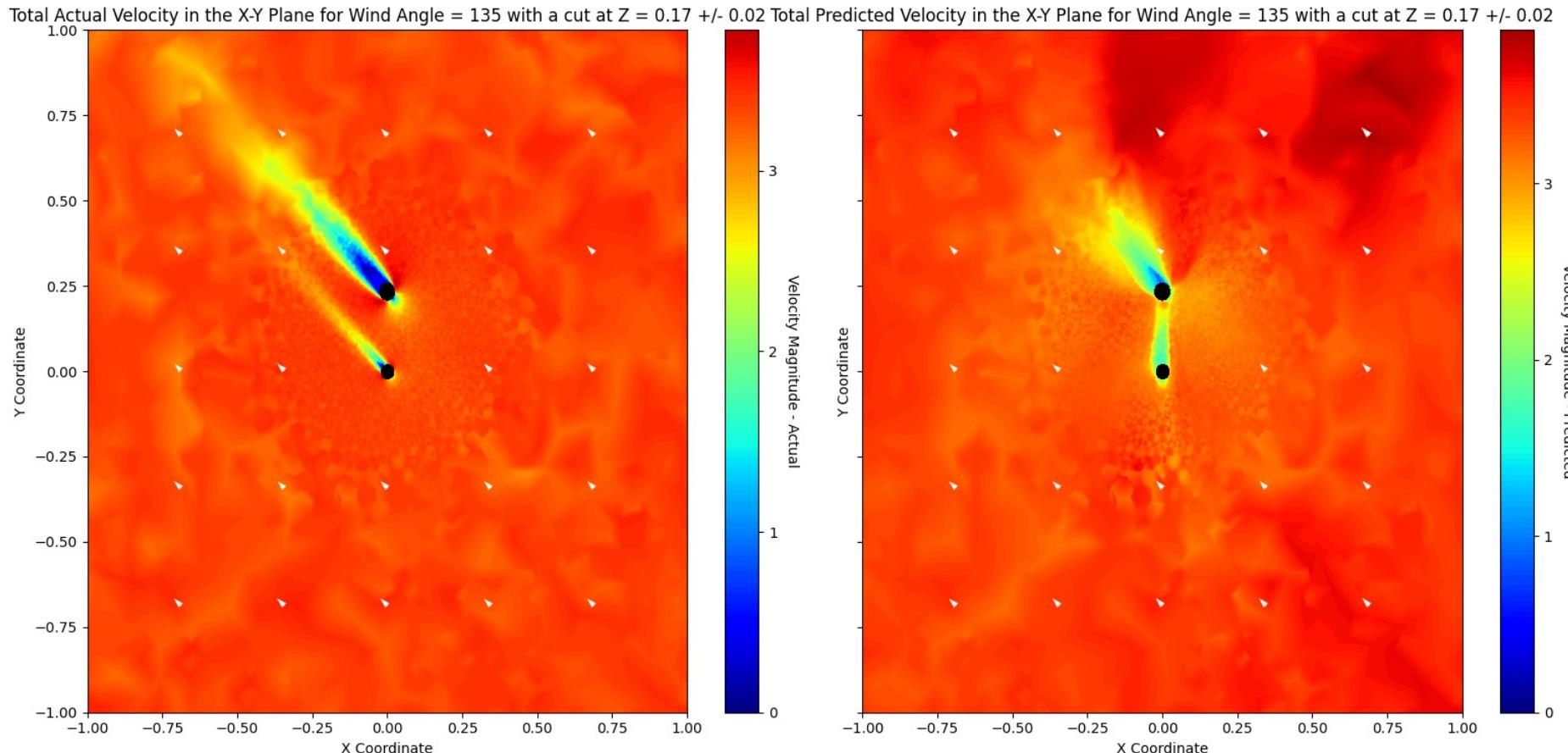
Progress so far - Data + No Slip + Inlet Loss (Adam Optimizer – Std Normal Scalar), Threshold = 1E-5 (6580 Epochs, so far...), GPU Workstation
Predicting Results - X-Y Total Velocity Plot (Angle = 135)

Comparison of Actual vs. Predicted values with Wind Angle = 135 in the X-Y Plane with a cut at Z = 0.17 +/- 0.02



Progress so far - Data + No Slip + Inlet Loss (Adam Optimizer – Std Normal Scalar), Threshold = 1E-5 (6580 Epochs, so far...), GPU Workstation
Predicting Results - X-Y Total Velocity Plot (Angle = 135)

Comparison of Actual vs. Predicted values with Wind Angle = 135 in the X-Y Plane with a cut at Z = 0.17 +/- 0.02

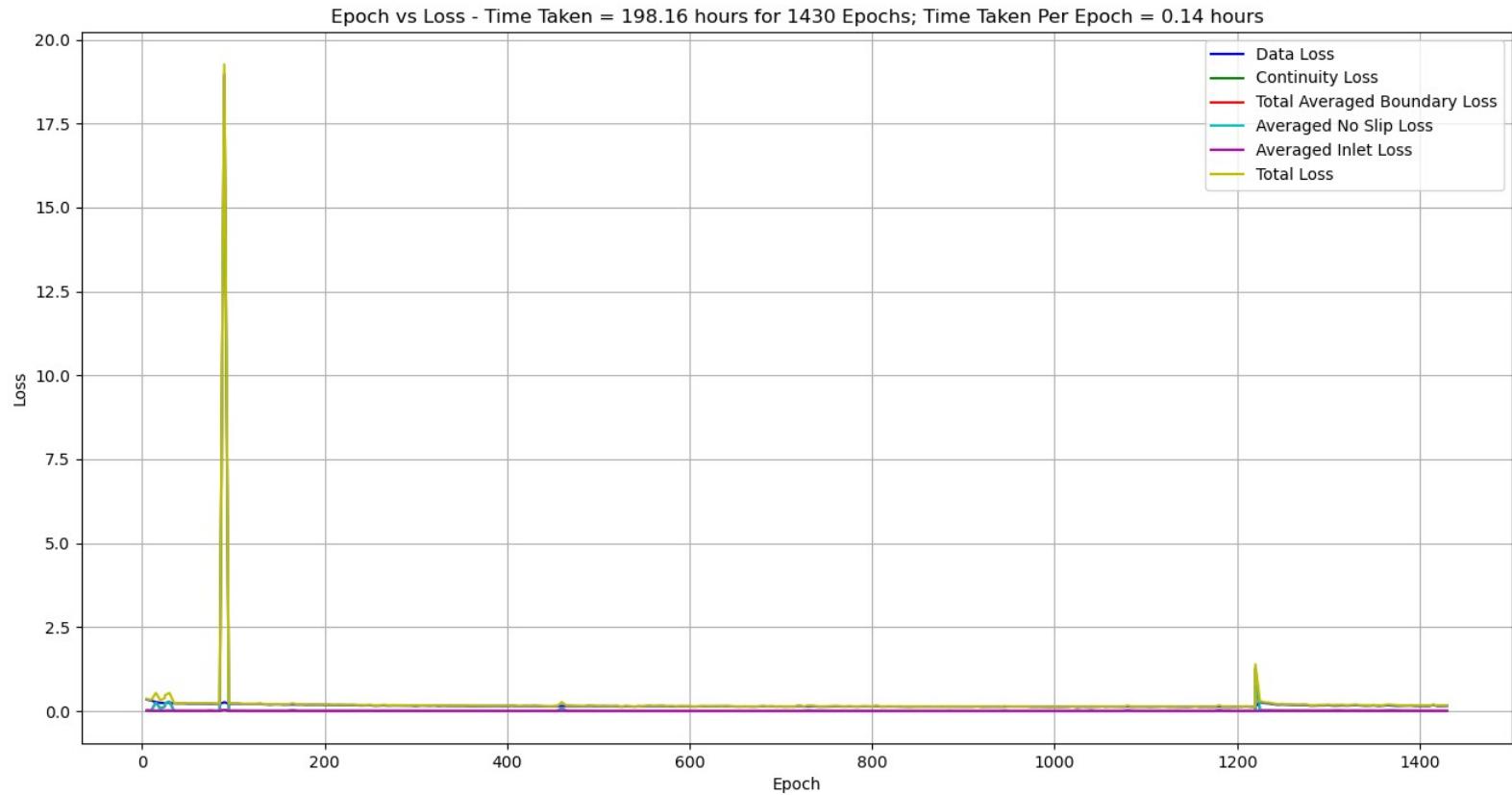


Progress so far – Data + Cont + No Slip + Inlet Loss
Standard Normal Scalar
(Adam Optimizer)

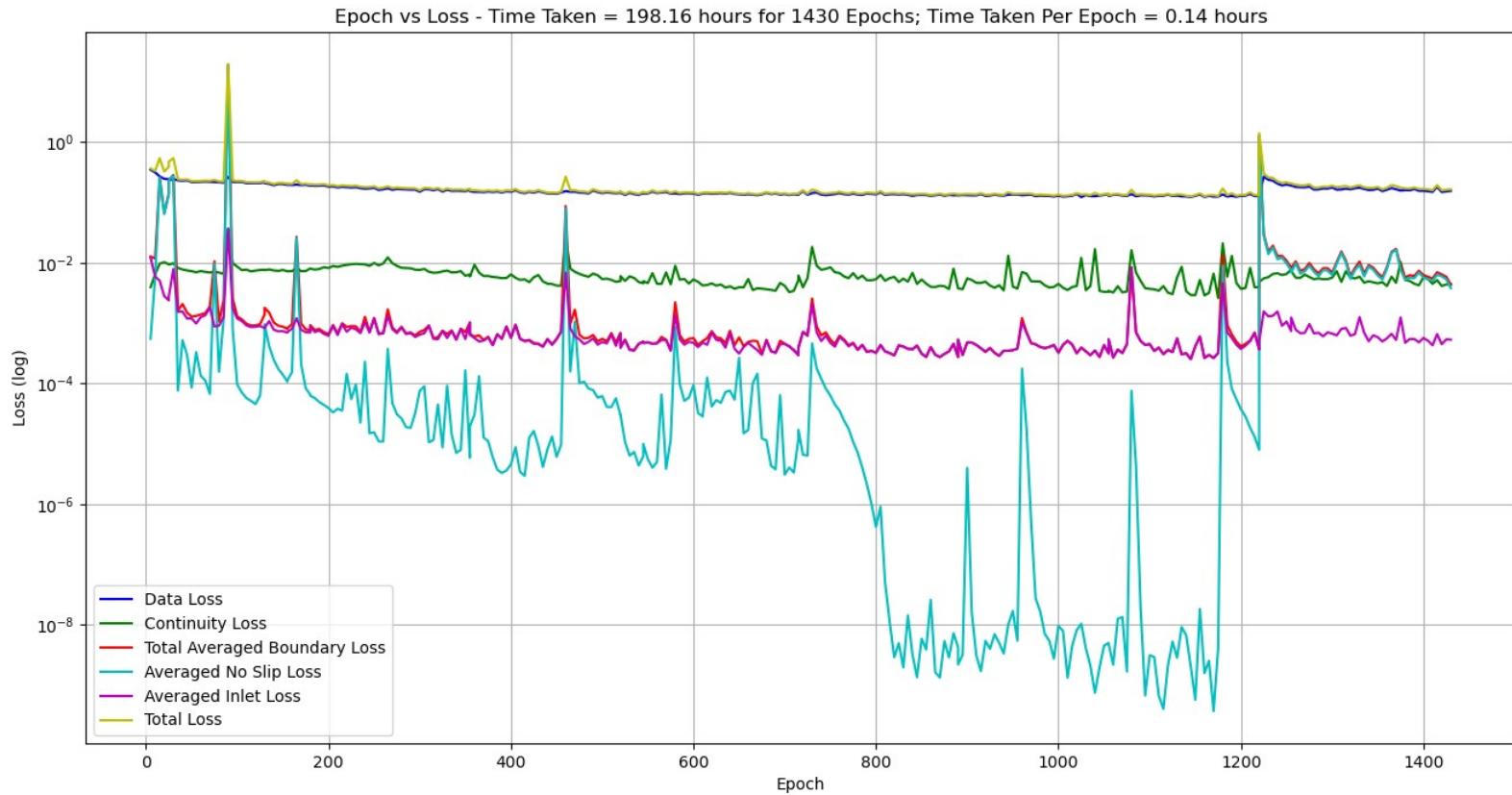
Threshold = 1E-5 (1430 Epochs, not completed), Google Colab

Scripts v4 – PREDICTING (135 DEG)

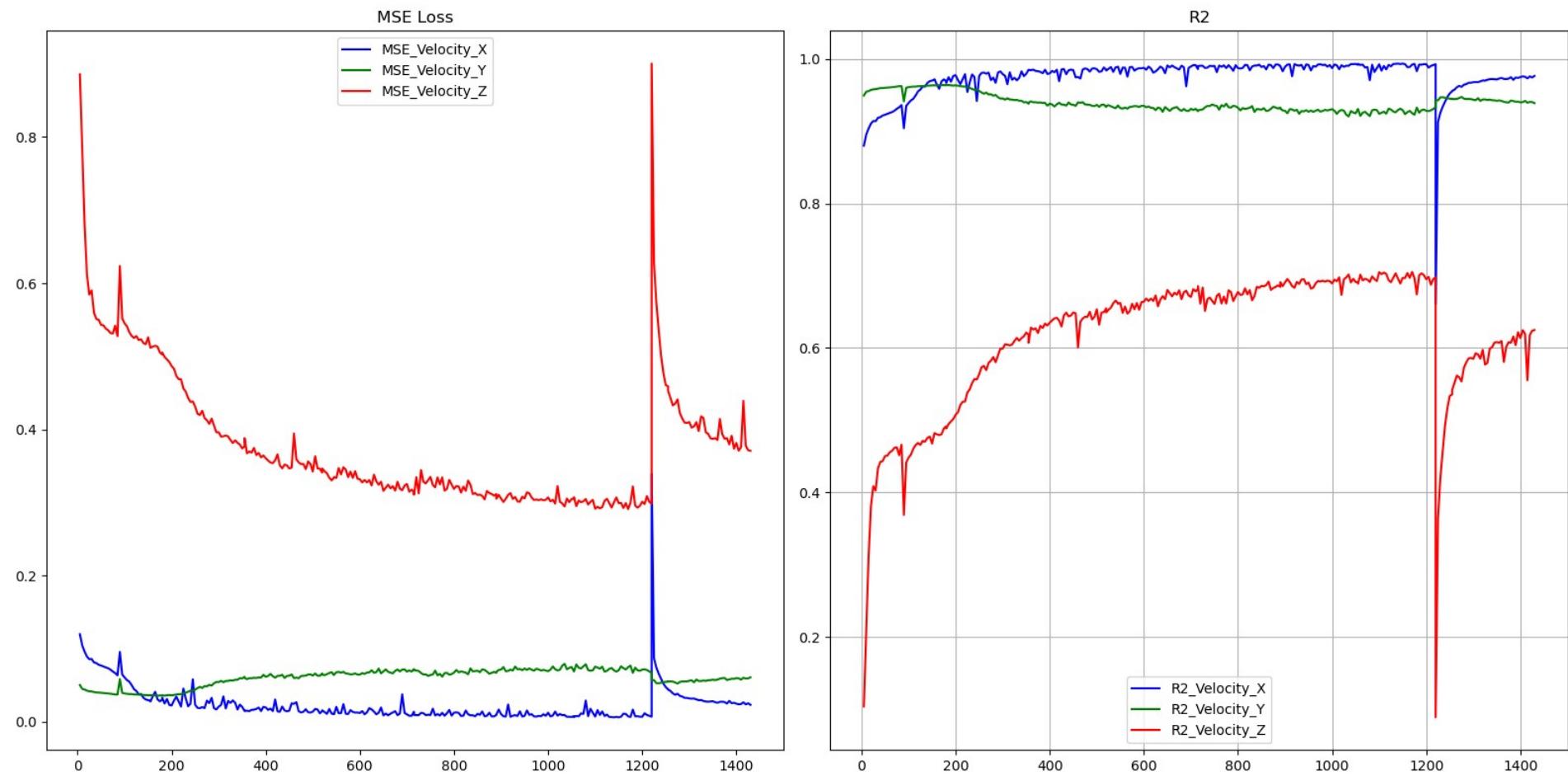
Progress so far - Data + Cont + No Slip + Inlet Loss (Adam Optimizer – Std Normal Scalar)
Logging Plots (Training)



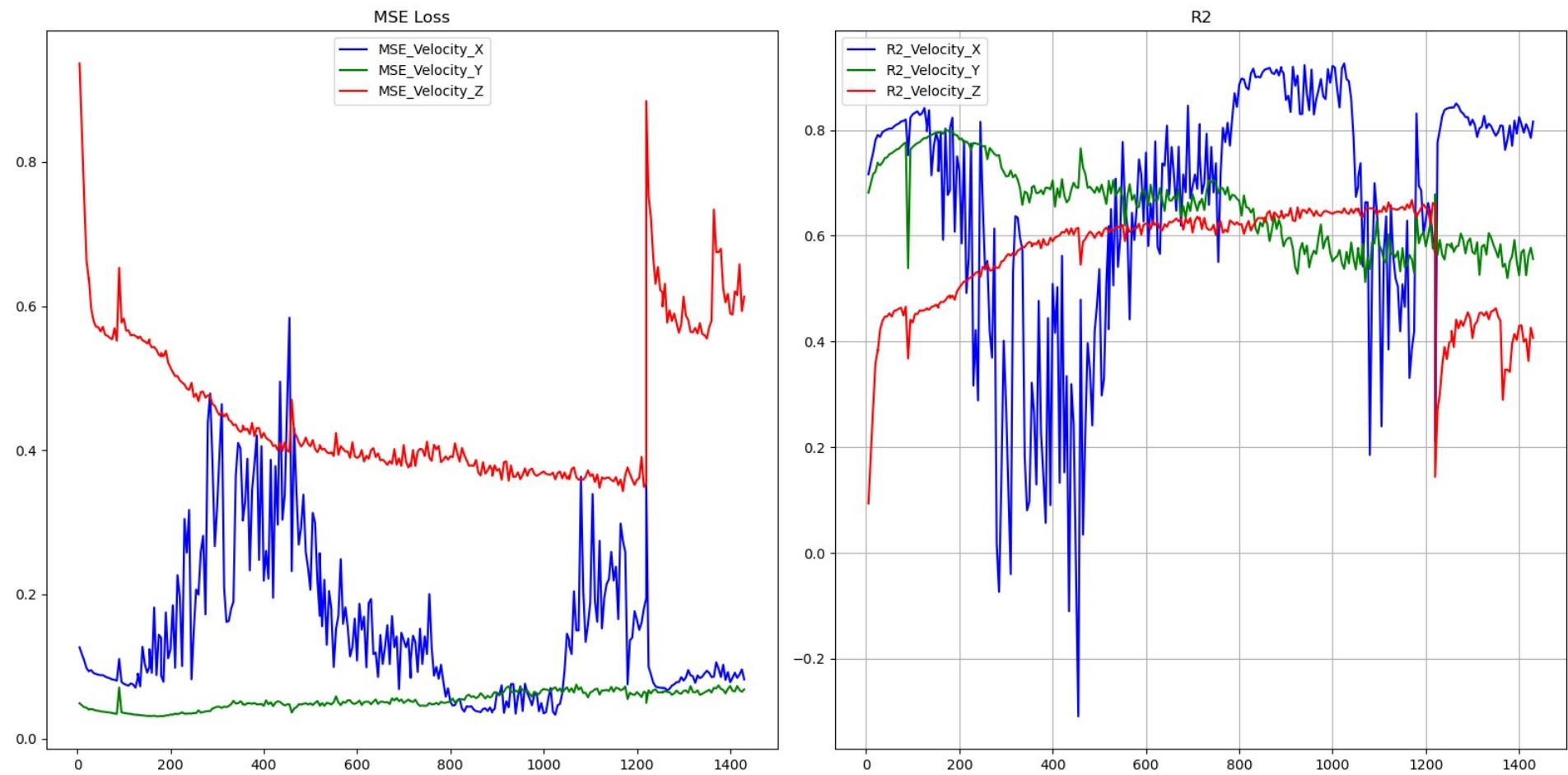
Progress so far - Data + Cont + No Slip + Inlet Loss (Adam Optimizer – Std Normal Scalar)
Logging Plots (Training)



Progress so far - Data + Cont + No Slip + Inlet Loss (Adam Optimizer – Std Normal Scalar)
Logging Plots (Testing)



Progress so far - Data + Cont + No Slip + Inlet Loss (Adam Optimizer – Std Normal Scalar)
Logging Plots (Predicting 135)



Progress so far - Data + Cont + No Slip + Inlet Loss (Adam Optimizer – Std Normal Scalar)
Threshold = 1E-5 (305 Epochs, so far...), Google Colab
Predicting Results – Metrics (Angle = 135)

Variable	MSE	RMSE	MAE	R2
Velocity:0	0.897047555002864	0.947125944636121	0.442709809320301	0.119874805241339
Velocity:1	0.295321045145586	0.54343449020612	0.315580757770724	0.713012439942471
Velocity:2	0.0142119835311582	0.119214024054044	0.0531496399240948	0.565569558590656

Progress so far - Data + Cont + No Slip + Inlet Loss (Adam Optimizer – Std Normal Scalar)
Threshold = 1E-5 (520 Epochs, so far...), Google Colab
Predicting Results – Metrics (Angle = 135)

Variable	MSE	RMSE	MAE	R2
Velocity:0	0.388988026275427	0.623689046140324	0.258345273202646	0.618350041226795
Velocity:1	0.31056314460933	0.557281925607973	0.309681037424798	0.698200448019926
Velocity:2	0.0127888798913347	0.113087929910025	0.0510117801191898	0.609070843338441

Progress so far - Data + Cont + No Slip + Inlet Loss (Adam Optimizer – Std Normal Scalar)
Threshold = 1E-5 (895 Epochs, so far...), Google Colab
Predicting Results – Metrics (Angle = 135)

Variable	MSE	RMSE	MAE	R2
Velocity:0	0.0942843554028923	0.307057576690256	0.140852238963411	0.907494272517804
Velocity:1	0.432065625507323	0.657316990125254	0.348568076302003	0.580126571785804
Velocity:2	0.0120019940511103	0.109553612679411	0.0486058054221221	0.633124288246957

Progress so far - Data + Cont + No Slip + Inlet Loss (Adam Optimizer – Std Normal Scalar)
Threshold = 1E-5 (1220 Epochs, so far...), Google Colab
Predicting Results – Metrics (Angle = 135)

Variable	MSE	RMSE	MAE	R2
Velocity:0	0.445142086415141	0.667189692977298	0.242224463274455	0.56325529977042
Velocity:1	0.422385252674968	0.649911726832935	0.330796289314114	0.589533780060565
Velocity:2	0.0112113814357317	0.105883811018171	0.0477130398545147	0.657291652832605

Progress so far - Data + Cont + No Slip + Inlet Loss (Adam Optimizer – Std Normal Scalar)
Threshold = 1E-5 (1325 Epochs, so far...), Google Colab
Predicting Results – Metrics (Angle = 135)

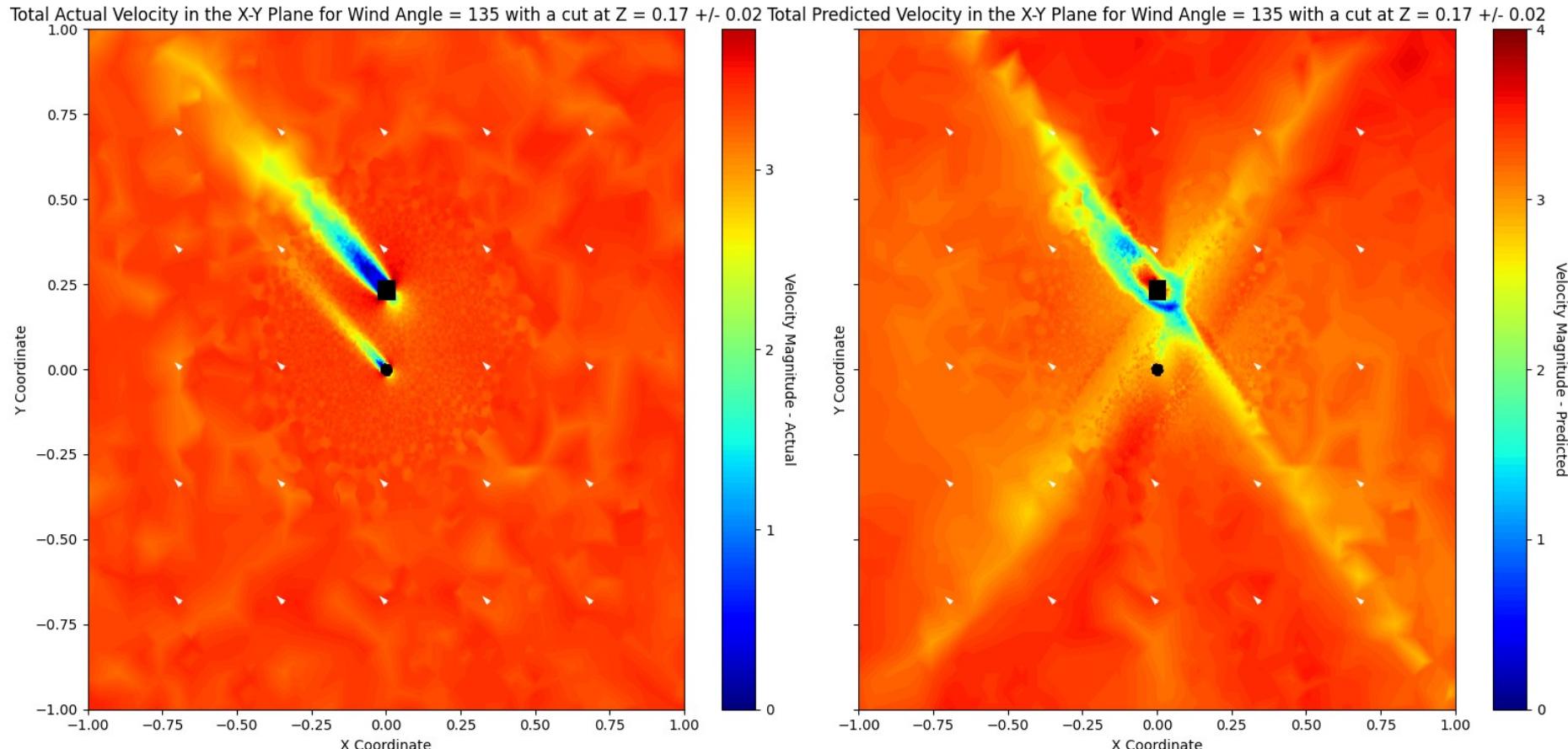
Variable	MSE	RMSE	MAE	R2
Velocity:0	0.176463740044868	0.420075874152358	0.214612415471994	0.826865161485964
Velocity:1	0.428924732156823	0.654923455189095	0.353776521902061	0.583178834175761
Velocity:2	0.0180347750532767	0.134293615087526	0.0540906477134365	0.448714863063543

Progress so far - Data + Cont + No Slip + Inlet Loss (Adam Optimizer – Std Normal Scalar)
Threshold = 1E-5 (1410 Epochs, so far...), Google Colab
Predicting Results – Metrics (Angle = 135)

Variable	MSE	RMSE	MAE	R2
Velocity:0	0.209007128219743	0.457172974069709	0.231040094576876	0.794935688298306
Velocity:1	0.438639206340597	0.662298426950115	0.34761684766938	0.573738486834891
Velocity:2	0.0196482061699141	0.140172059162709	0.0558490970195353	0.399395667706494

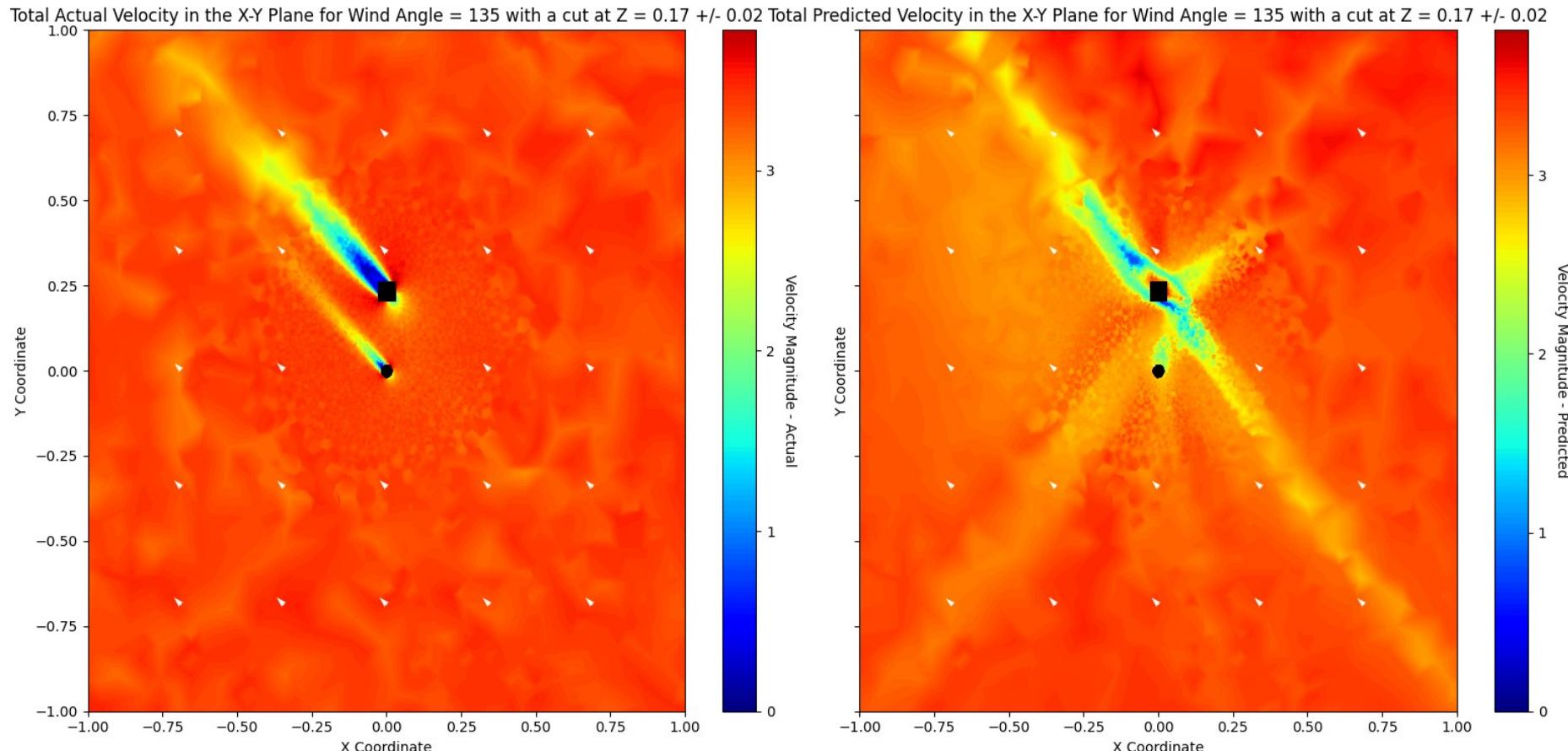
Progress so far - Data + Cont + No Slip + Inlet Loss (Adam Optimizer – Std Normal Scalar), Threshold = 1E-5 (305 Epochs, so far...), Google Colab
Predicting Results - X-Y Total Velocity Plot (Angle = 135)

Comparison of Actual vs. Predicted values with Wind Angle = 135 in the X-Y Plane with a cut at Z = 0.17 +/- 0.02



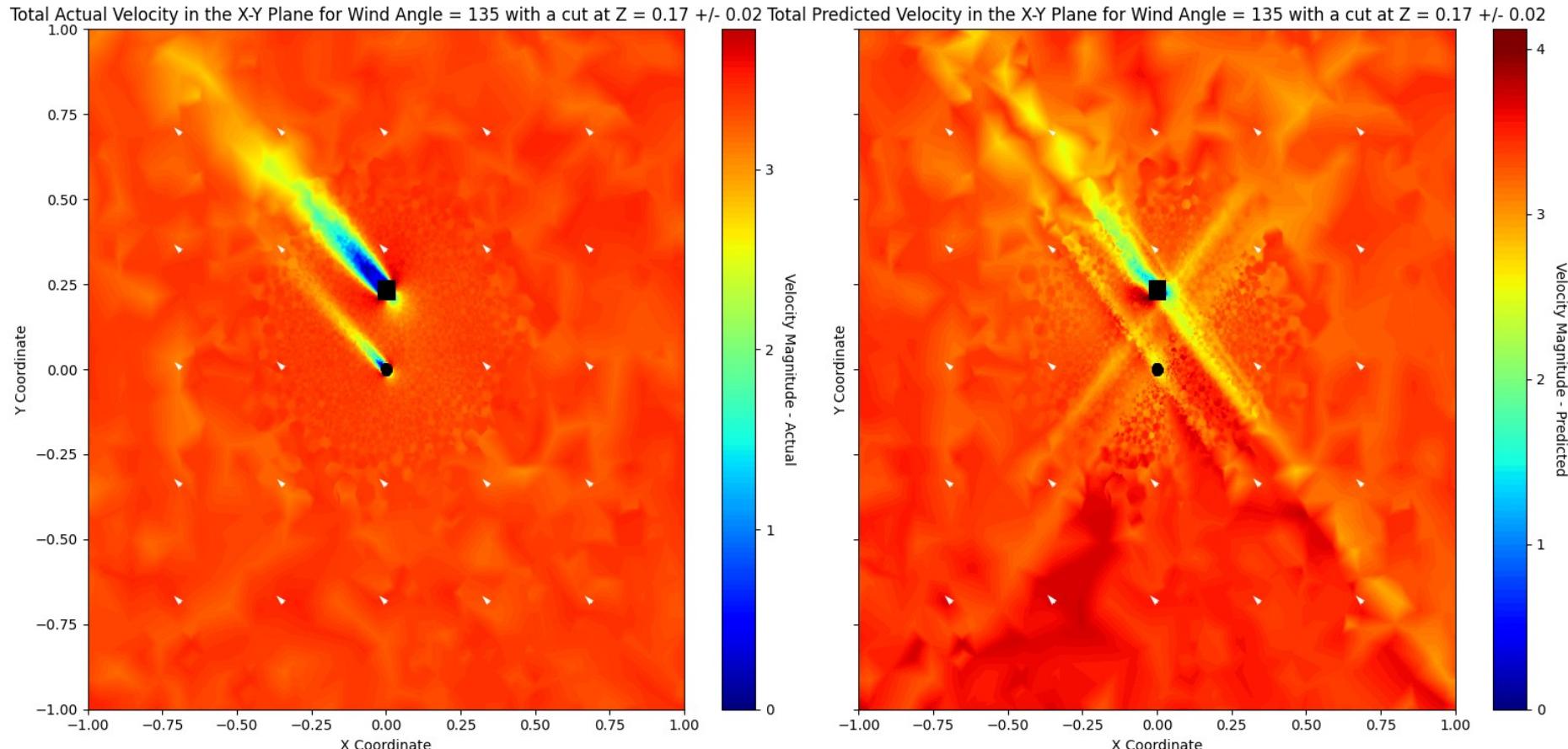
Progress so far - Data + Cont + No Slip + Inlet Loss (Adam Optimizer – Std Normal Scalar), Threshold = 1E-5 (520 Epochs, so far...), Google Colab
Predicting Results - X-Y Total Velocity Plot (Angle = 135)

Comparison of Actual vs. Predicted values with Wind Angle = 135 in the X-Y Plane with a cut at Z = 0.17 +/- 0.02

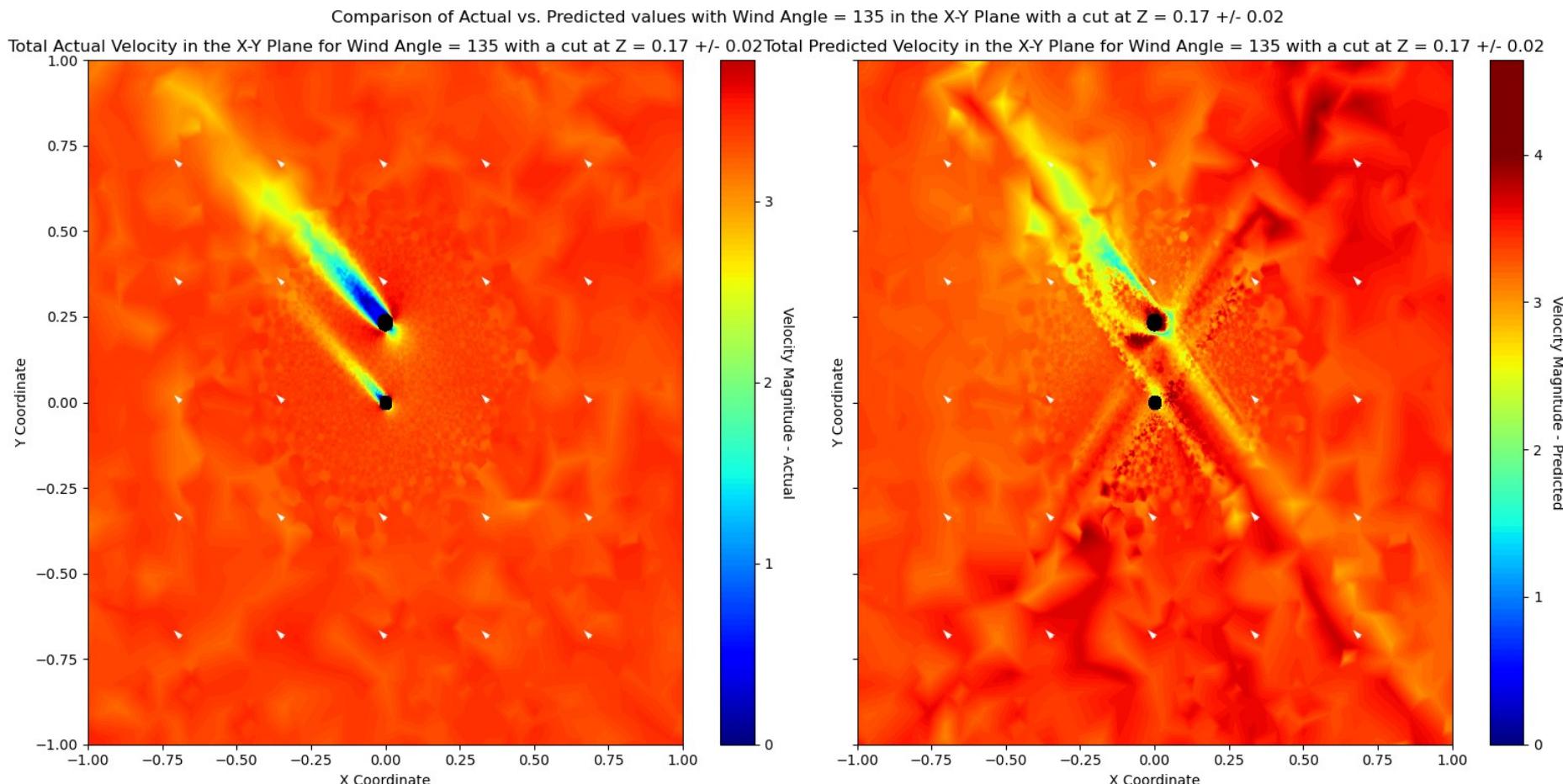


Progress so far - Data + Cont + No Slip + Inlet Loss (Adam Optimizer – Std Normal Scalar), Threshold = 1E-5 (895 Epochs, so far...), Google Colab
Predicting Results - X-Y Total Velocity Plot (Angle = 135)

Comparison of Actual vs. Predicted values with Wind Angle = 135 in the X-Y Plane with a cut at Z = 0.17 +/- 0.02

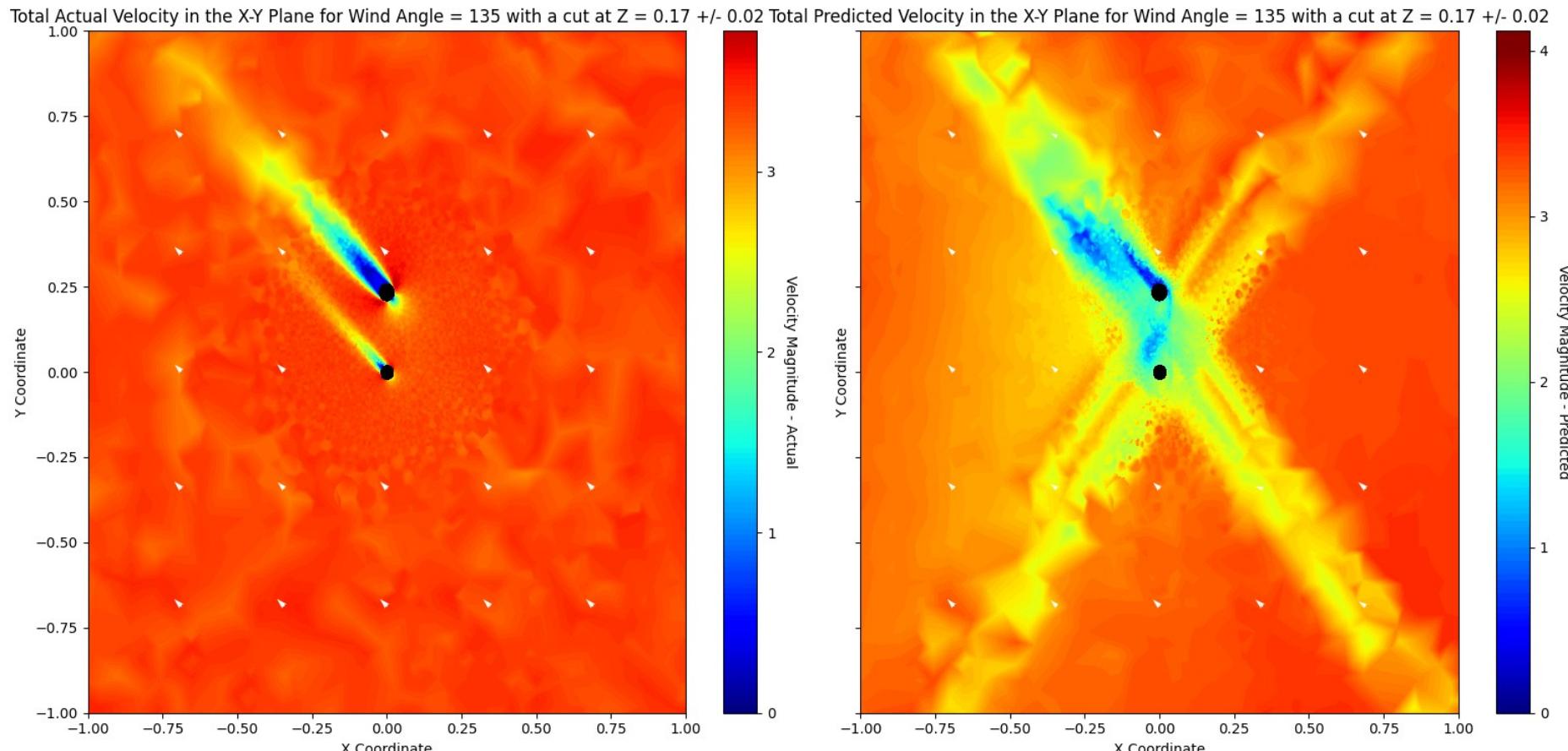


Progress so far - Data + Cont + No Slip + Inlet Loss (Adam Optimizer – Std Normal Scalar), Threshold = 1E-5 (1220 Epochs, so far...), Google Colab
Predicting Results - X-Y Total Velocity Plot (Angle = 135)



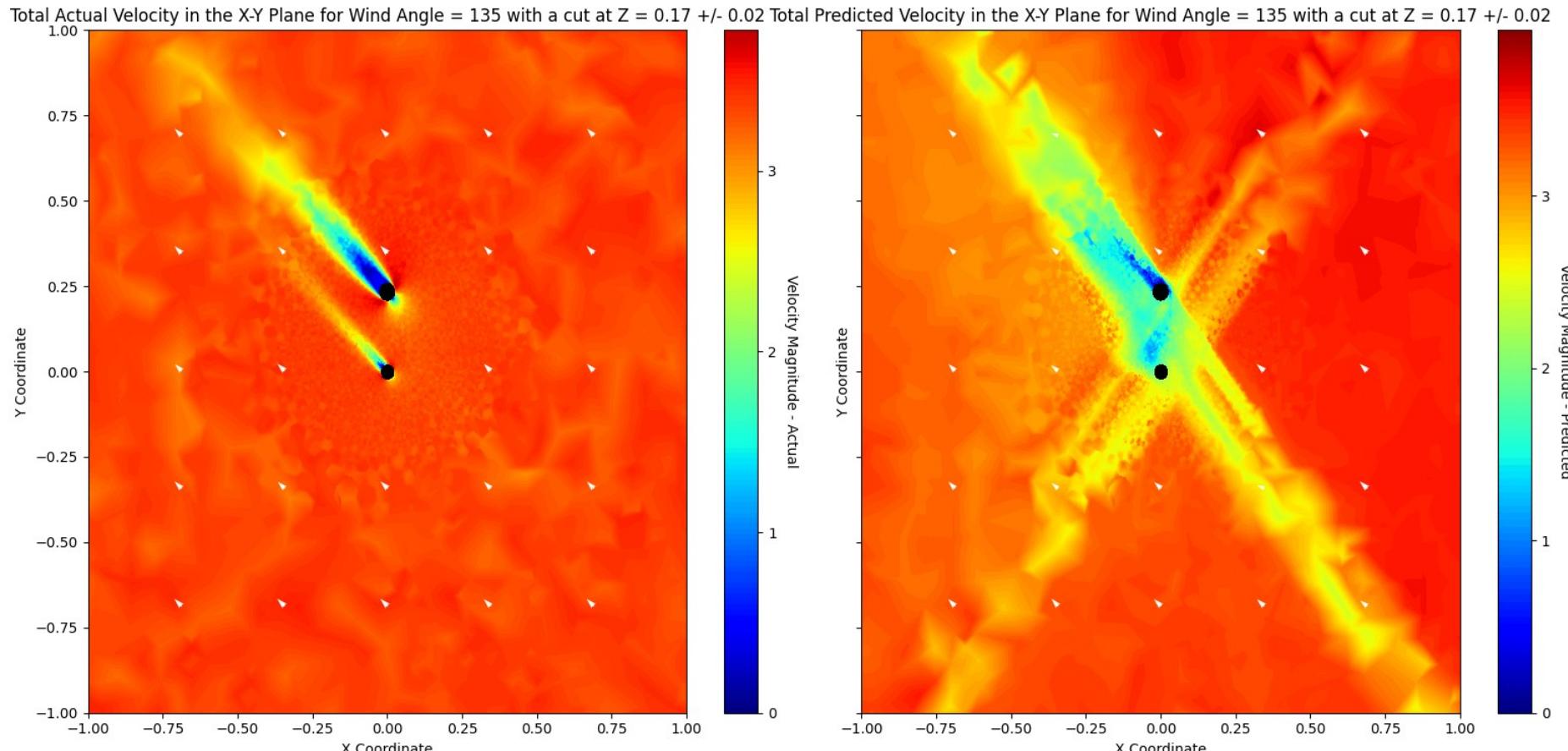
Progress so far - Data + Cont + No Slip + Inlet Loss (Adam Optimizer – Std Normal Scalar), Threshold = 1E-5 (1325 Epochs, so far...), Google Colab
Predicting Results - X-Y Total Velocity Plot (Angle = 135)

Comparison of Actual vs. Predicted values with Wind Angle = 135 in the X-Y Plane with a cut at Z = 0.17 +/- 0.02



Progress so far - Data + Cont + No Slip + Inlet Loss (Adam Optimizer – Std Normal Scalar), Threshold = 1E-5 (1410 Epochs, so far...), Google Colab
Predicting Results - X-Y Total Velocity Plot (Angle = 135)

Comparison of Actual vs. Predicted values with Wind Angle = 135 in the X-Y Plane with a cut at Z = 0.17 +/- 0.02



Some Parameters

Infinite epochs - instead the criteria for stopping is $\text{loss}_{\{n\}} - \text{loss}_{\{n-1\}} < \epsilon$ for 10 consecutive epochs where n is the epoch number and $\epsilon = 1E-5$ (user defined)

128 Neurons for the PINN unless otherwise specified

We have the data for 13 angles, [0, 15, 30, 45, 60, 75, 90, 105, 120, 135, 150, 165, 180] in degrees

We concatenate the data for angles = [0, 15, 30, 45, 60, 75, 90, 105, 120, 135, 150, 165, 180] and then take 99% 1% of the dataset with random seed = 42 for training and 1% for testing

By using 99% 1% of the whole dataset we hope to make the NN learn about wind angle such that the parameters become functions of the wind angle relying on continuity loss and BC loss

Then using the trained neural network we predict the data for angle = 135

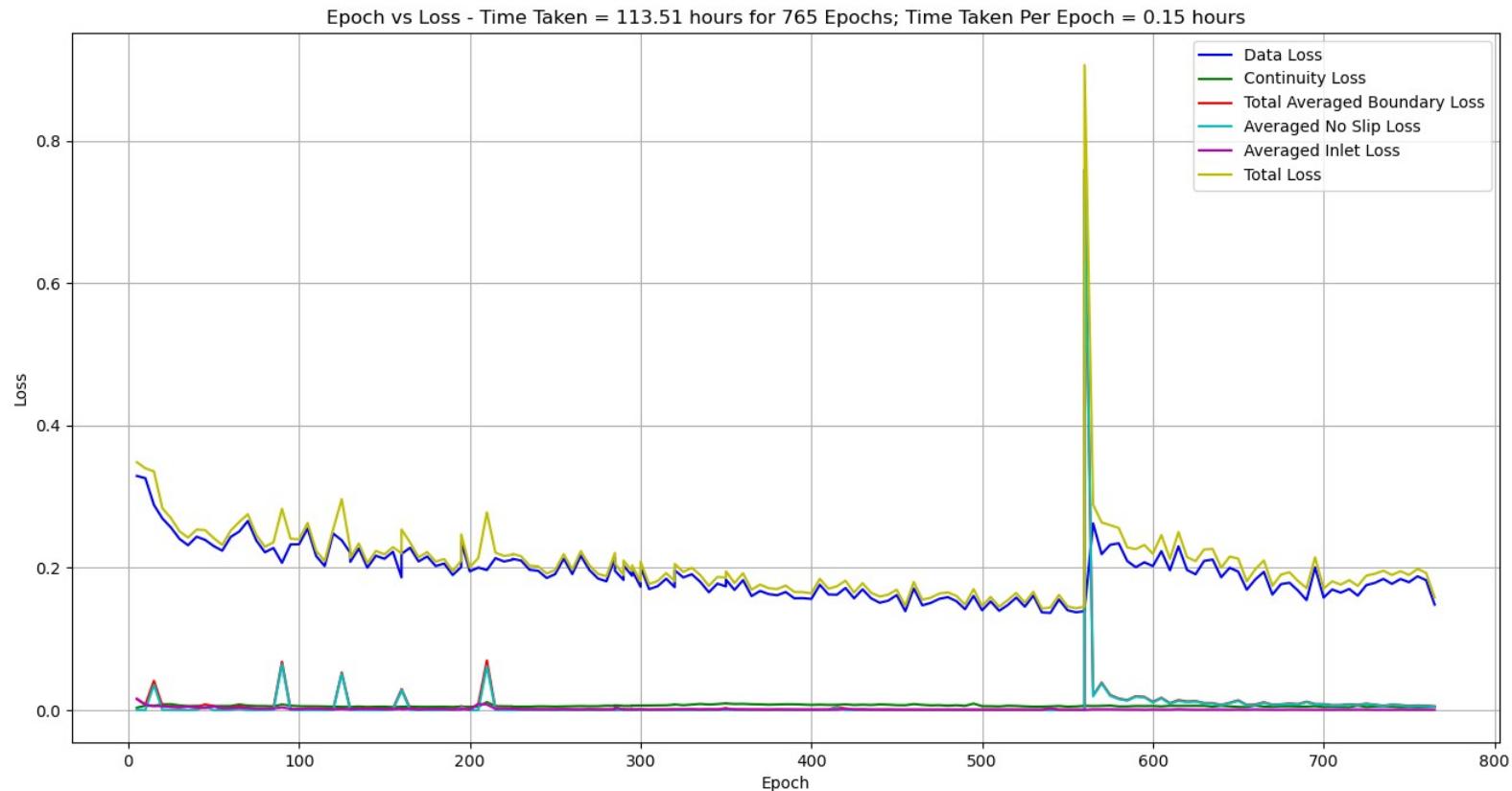
For this run, we will only have input parameters to be [X, Y, Z, $\cos(\theta)$, $\sin(\theta)$] and the output parameters will be [U, V, W]

Progress so far – 1% Data + Cont + No Slip + Inlet Loss
Standard Normal Scalar
(Adam Optimizer)

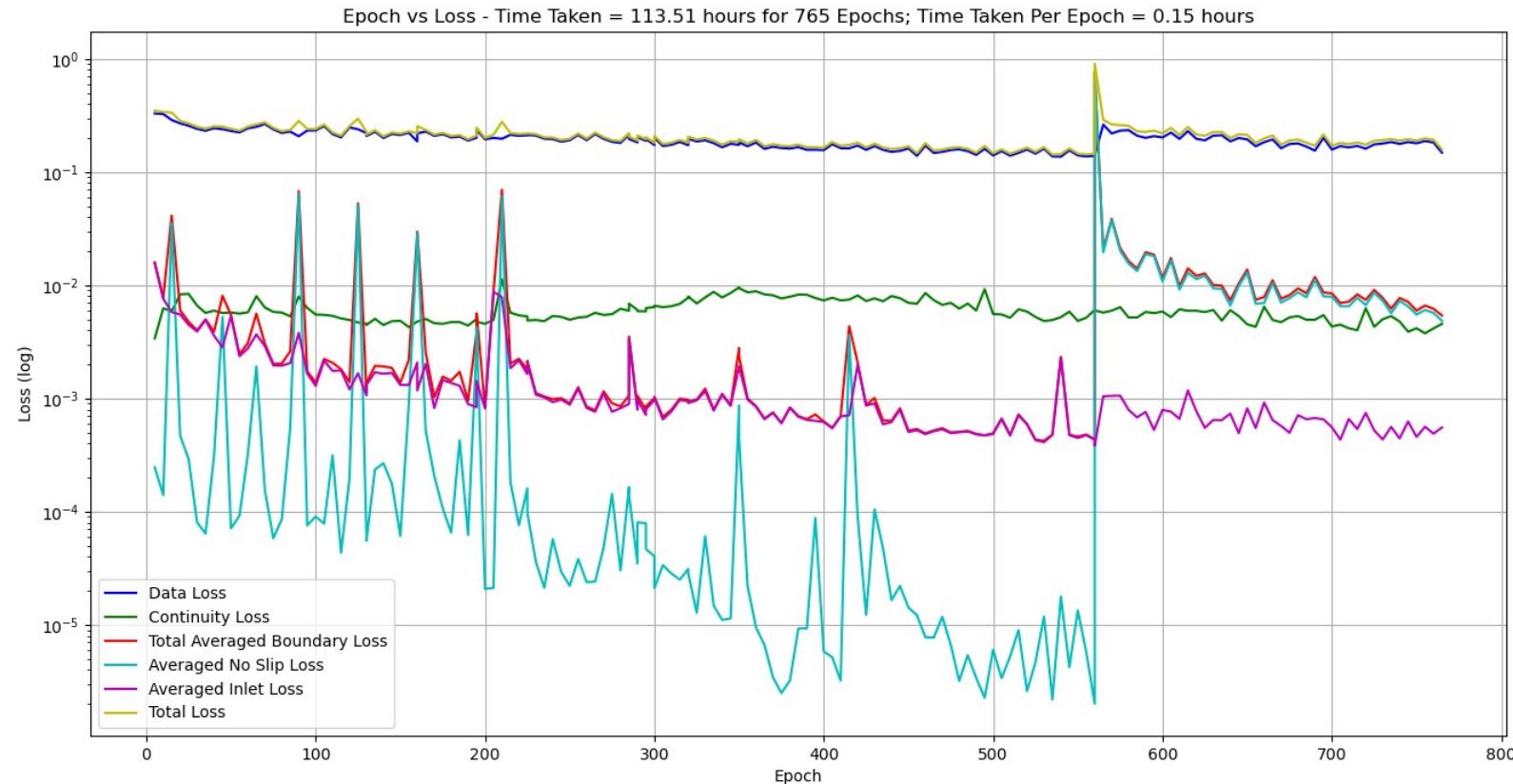
Threshold = 1E-5 (765 Epochs, not completed), Google
Colab

Scripts v4 – PREDICTING (135 DEG)

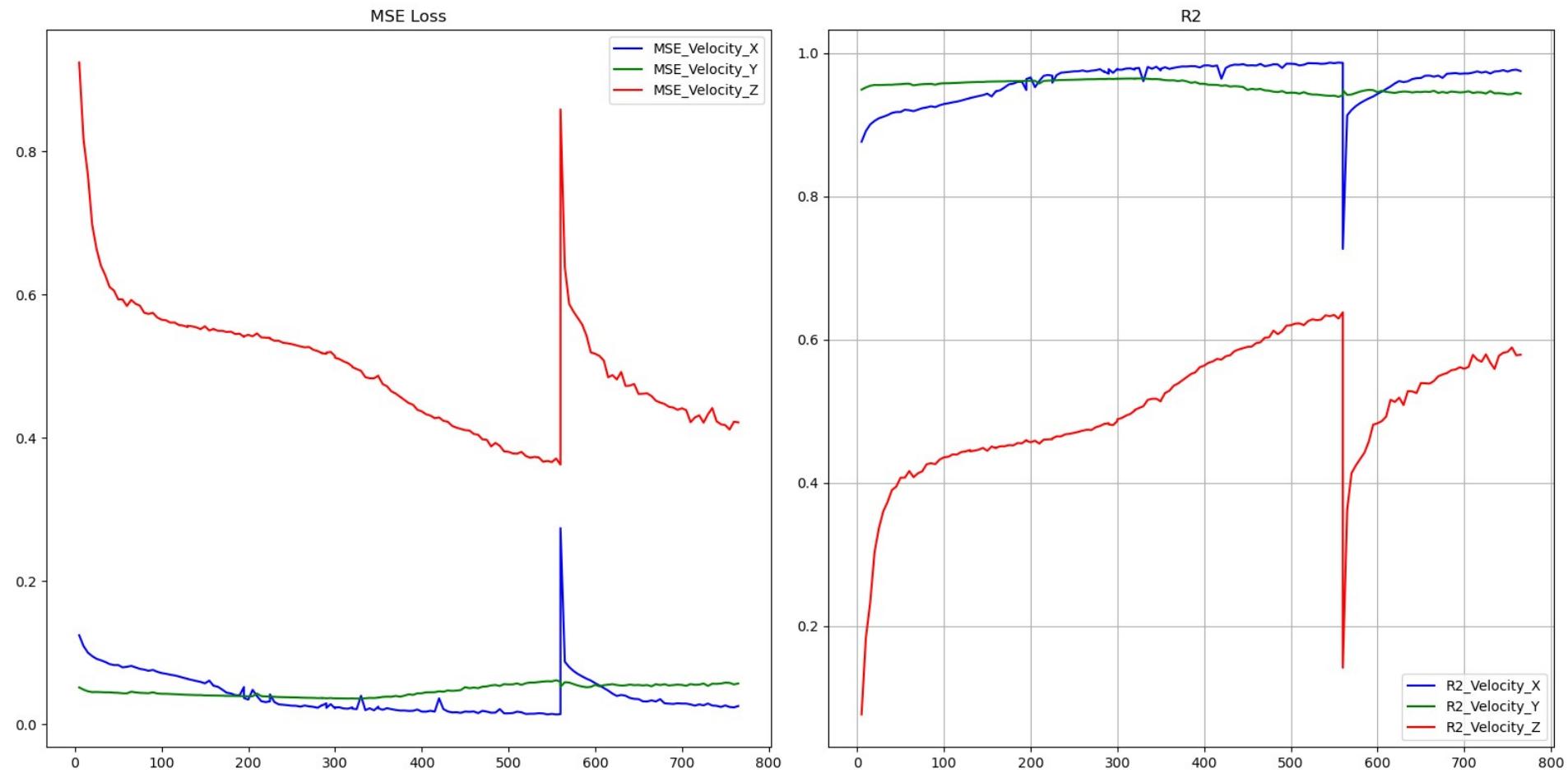
Progress so far – 1% Data + Cont + No Slip + Inlet Loss (Adam Optimizer – Std Normal Scalar)
Logging Plots (Training)



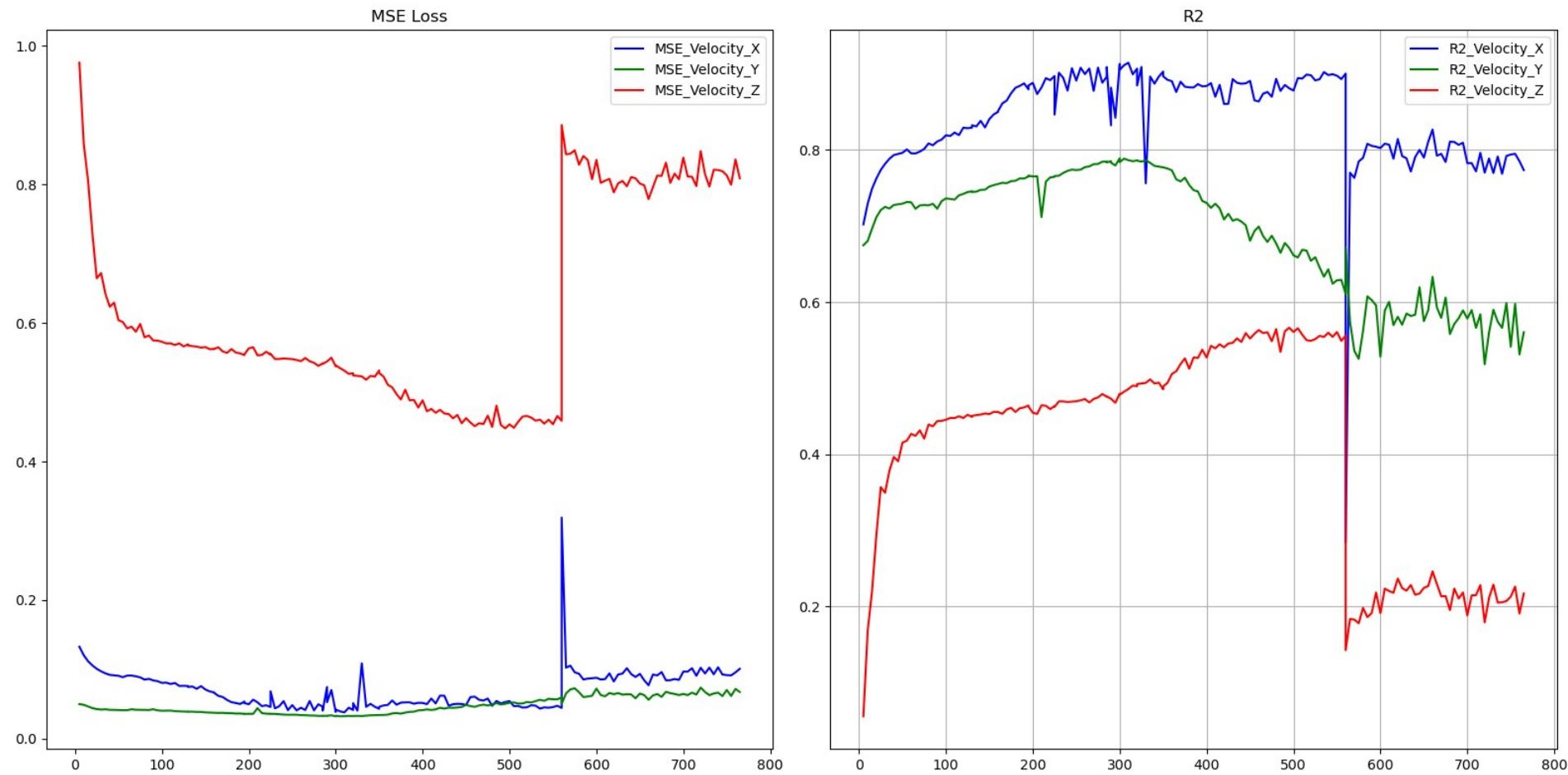
Progress so far – 1% Data + Cont + No Slip + Inlet Loss (Adam Optimizer – Std Normal Scalar)
Logging Plots (Training)



Progress so far - 1% Data + Cont + No Slip + Inlet Loss (Adam Optimizer – Std Normal Scalar)
Logging Plots (Testing)



Progress so far - 1% Data + Cont + No Slip + Inlet Loss (Adam Optimizer – Std Normal Scalar)
Logging Plots (Predicting 135)



Progress so far - 1% Data + Cont + No Slip + Inlet Loss (Adam Optimizer – Std Normal Scalar)
Threshold = 1E-5 (275 Epochs, so far...), Google Colab
Predicting Results – Metrics (Angle = 135)

Variable	MSE	RMSE	MAE	R2
Velocity:0	0.0936601533560144	0.30603946372325	0.154036213149849	0.908106699300546
Velocity:1	0.224778899040213	0.474108530866313	0.282394739582156	0.781564000099731
Velocity:2	0.0171776544213418	0.131063551078635	0.0548112155473902	0.474915237814621

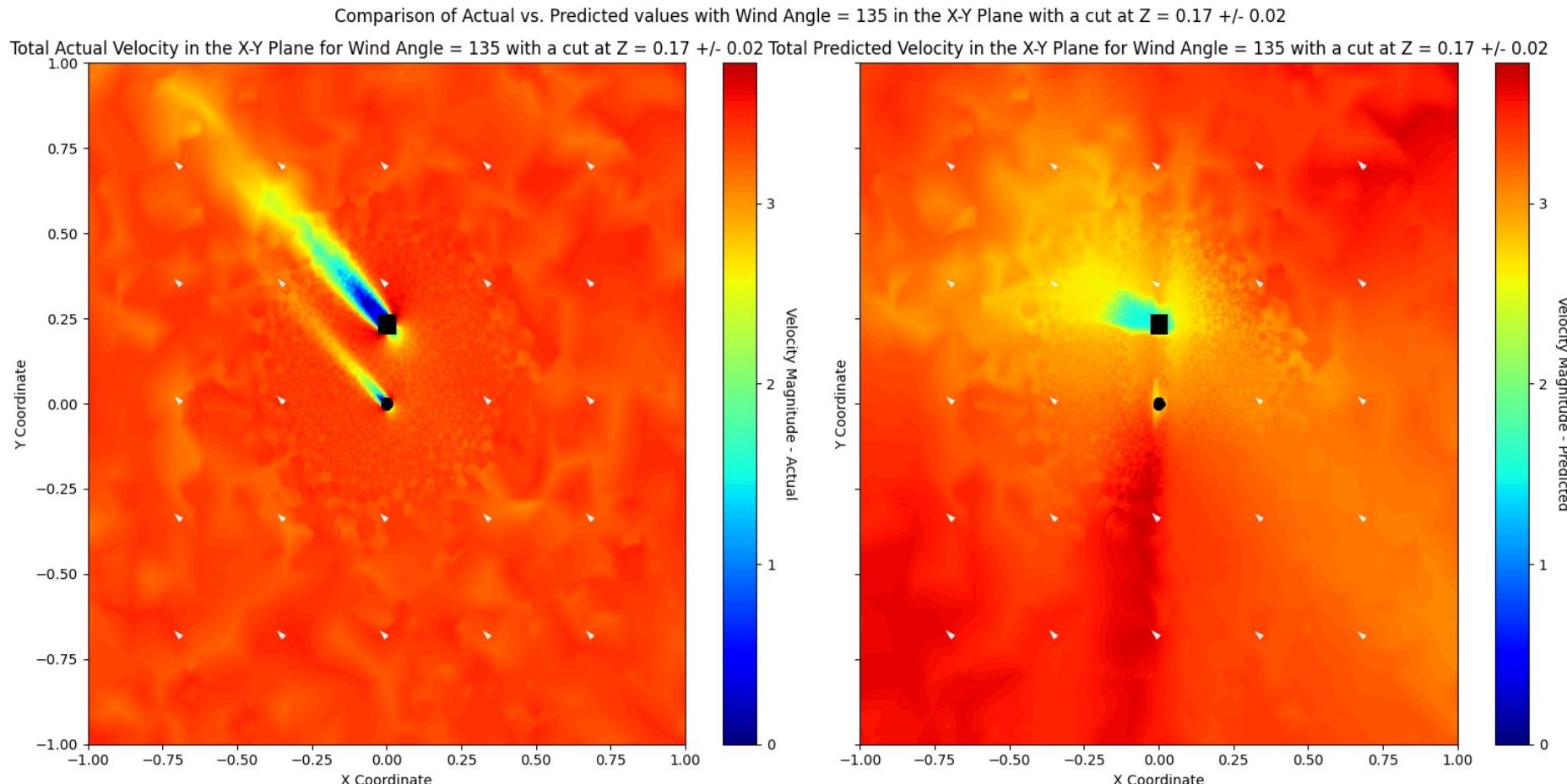
Progress so far - 1% Data + Cont + No Slip + Inlet Loss (Adam Optimizer – Std Normal Scalar)
Threshold = 1E-5 (560 Epochs, so far...), Google Colab
Predicting Results – Metrics (Angle = 135)

Variable	MSE	RMSE	MAE	R2
Velocity:0	0.101701480318671	0.318906695318036	0.147931407976381	0.900217068009924
Velocity:1	0.40047603431137	0.632831758298658	0.337888821770761	0.61082475550675
Velocity:2	0.0145267892793769	0.120527130885029	0.0523913151187033	0.555946609066613

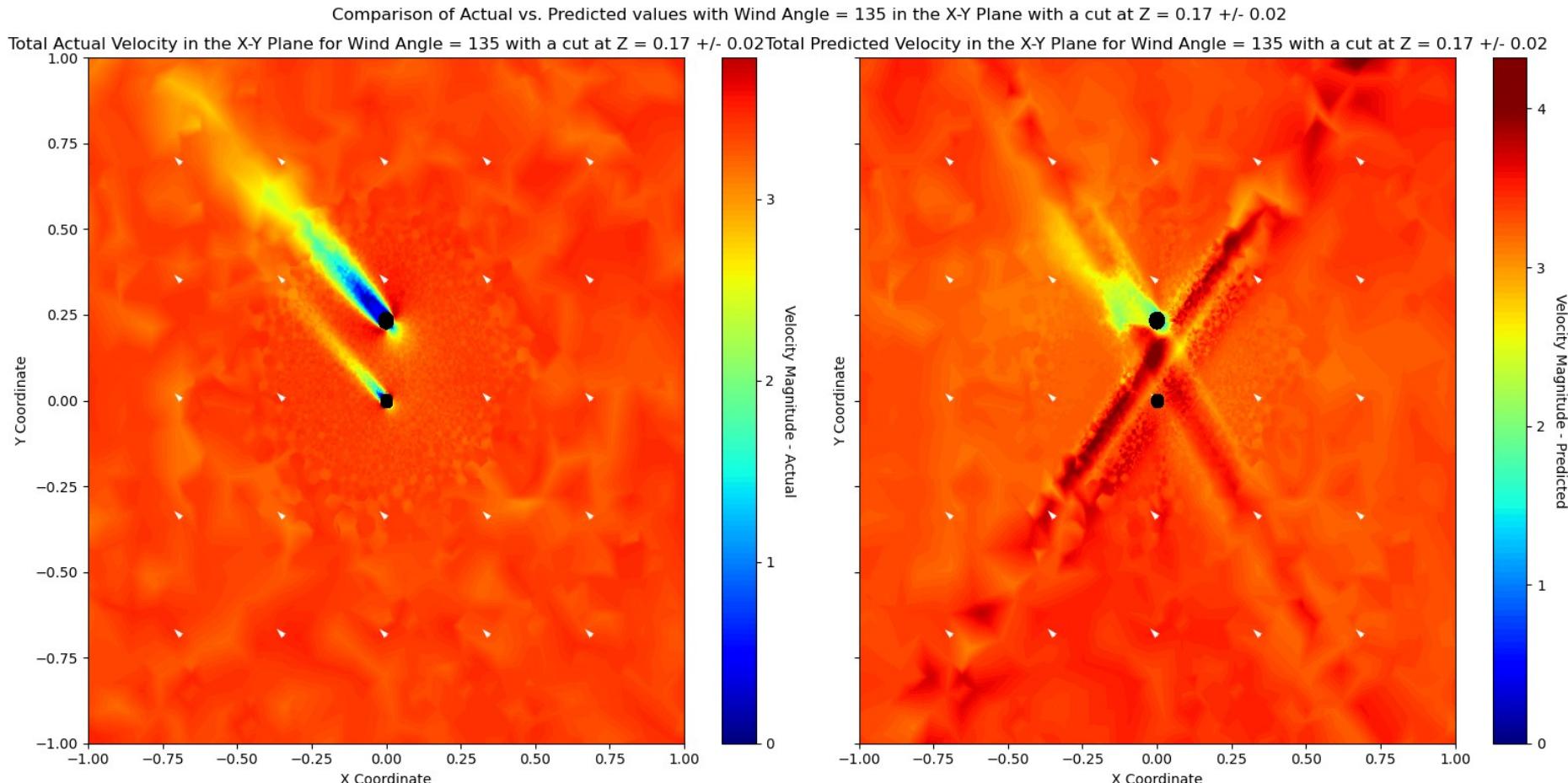
Progress so far - 1% Data + Cont + No Slip + Inlet Loss (Adam Optimizer – Std Normal Scalar)
Threshold = 1E-5 (765 Epochs, so far...), Google Colab
Predicting Results – Metrics (Angle = 135)

Variable	MSE	RMSE	MAE	R2
Velocity:0	0.230911053072058	0.480532052075674	0.231637135098651	0.773444970198571
Velocity:1	0.45228994945336	0.672525054888931	0.363615462291226	0.560472945745625
Velocity:2	0.0256062060522427	0.160019392738014	0.0609622903432647	0.217272144053217

Progress so far - 1% Data + Cont + No Slip + Inlet Loss (Adam Optimizer – Std Normal Scalar), Threshold = 1E-5 (275 Epochs, so far...), Google Colab
Predicting Results - X-Y Total Velocity Plot (Angle = 135)

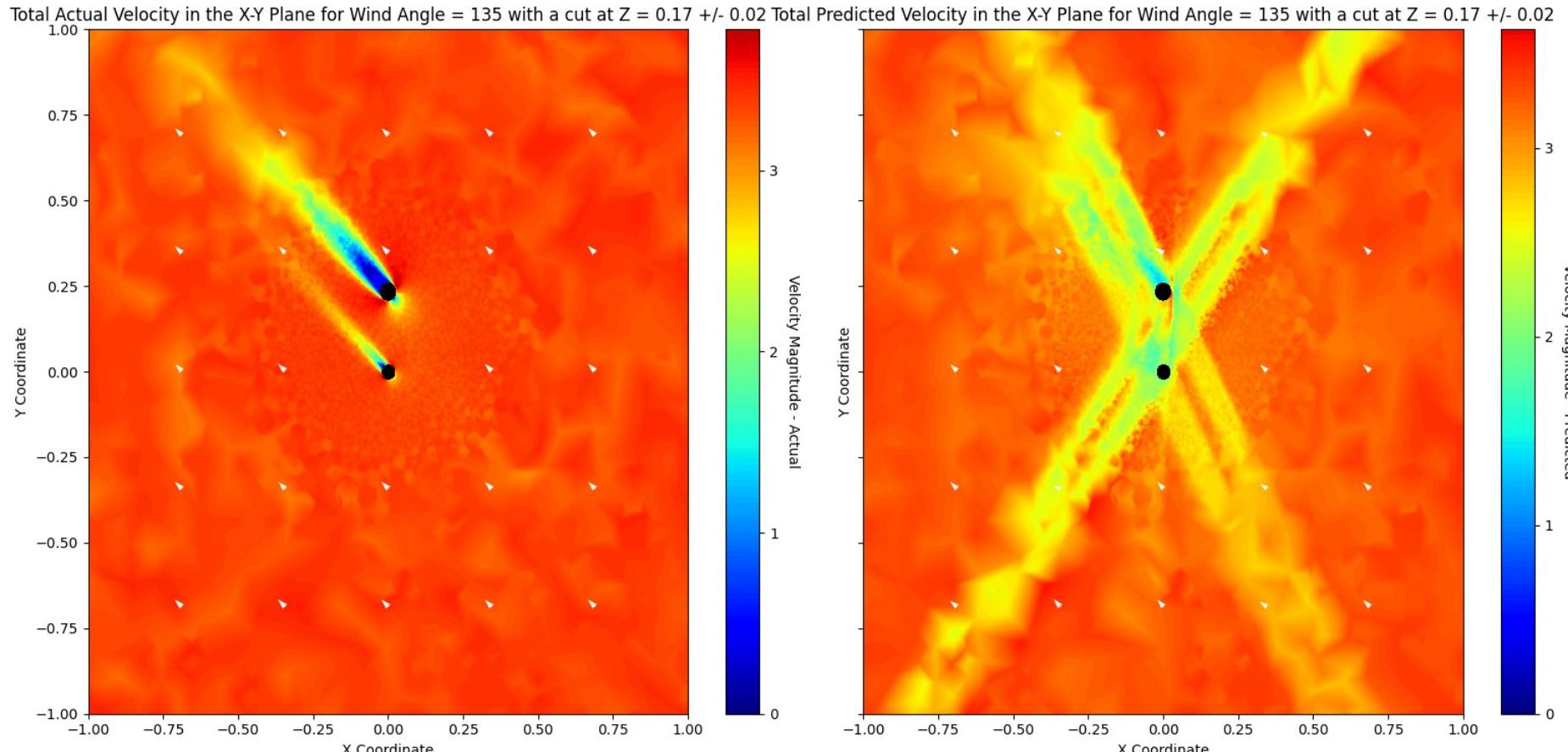


Progress so far - 1% Data + Cont + No Slip + Inlet Loss (Adam Optimizer – Std Normal Scalar), Threshold = 1E-5 (560 Epochs, so far...), Google Colab
Predicting Results - X-Y Total Velocity Plot (Angle = 135)



Progress so far - 1% Data + Cont + No Slip + Inlet Loss (Adam Optimizer – Std Normal Scalar), Threshold = 1E-5 (765 Epochs, so far...), Google Colab
Predicting Results - X-Y Total Velocity Plot (Angle = 135)

Comparison of Actual vs. Predicted values with Wind Angle = 135 in the X-Y Plane with a cut at Z = 0.17 +/- 0.02



Some Next Steps

Optimise TPU Script

Why does adding in more physics/boundary conditions result in something worse?

La Defense?